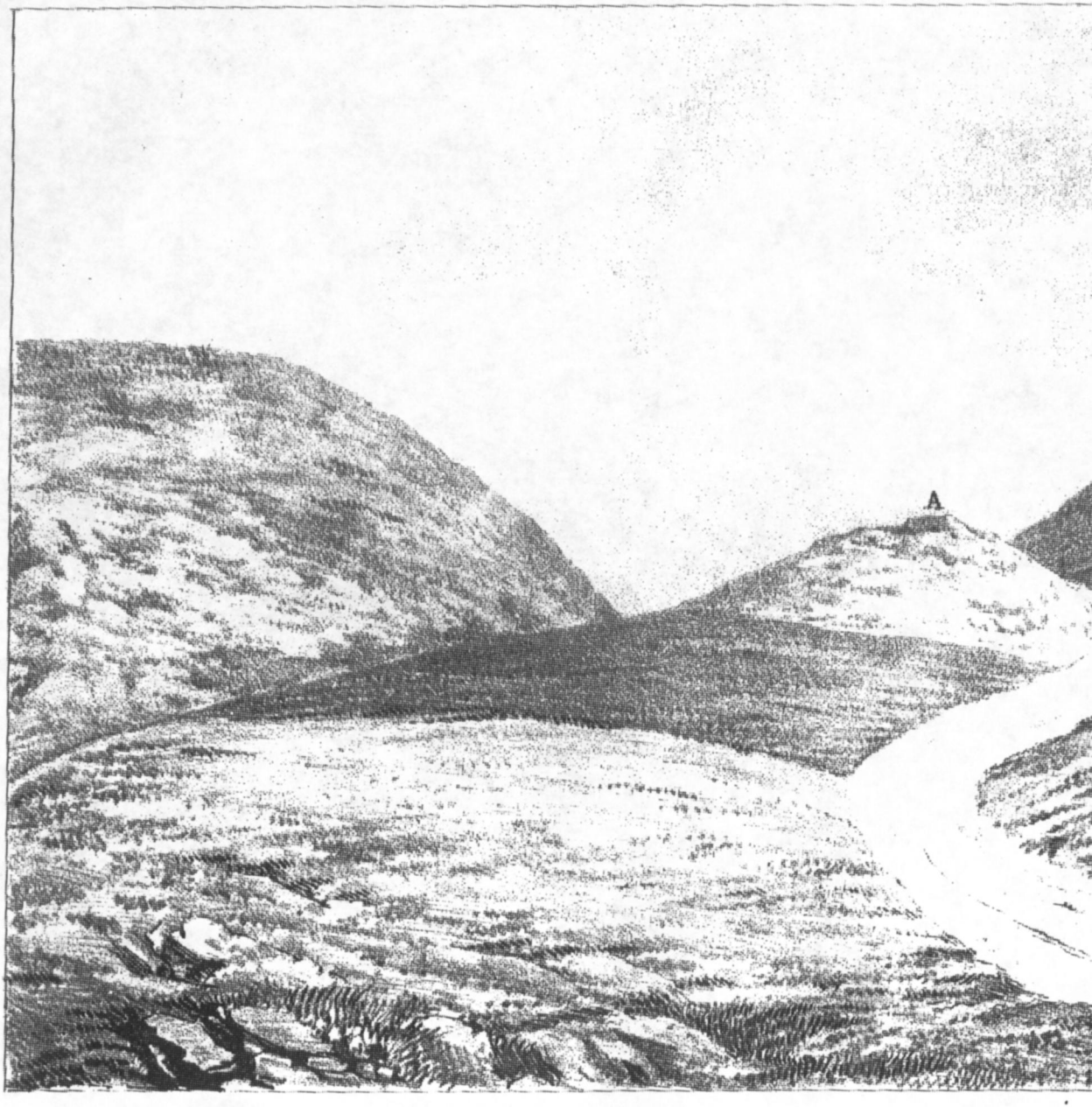
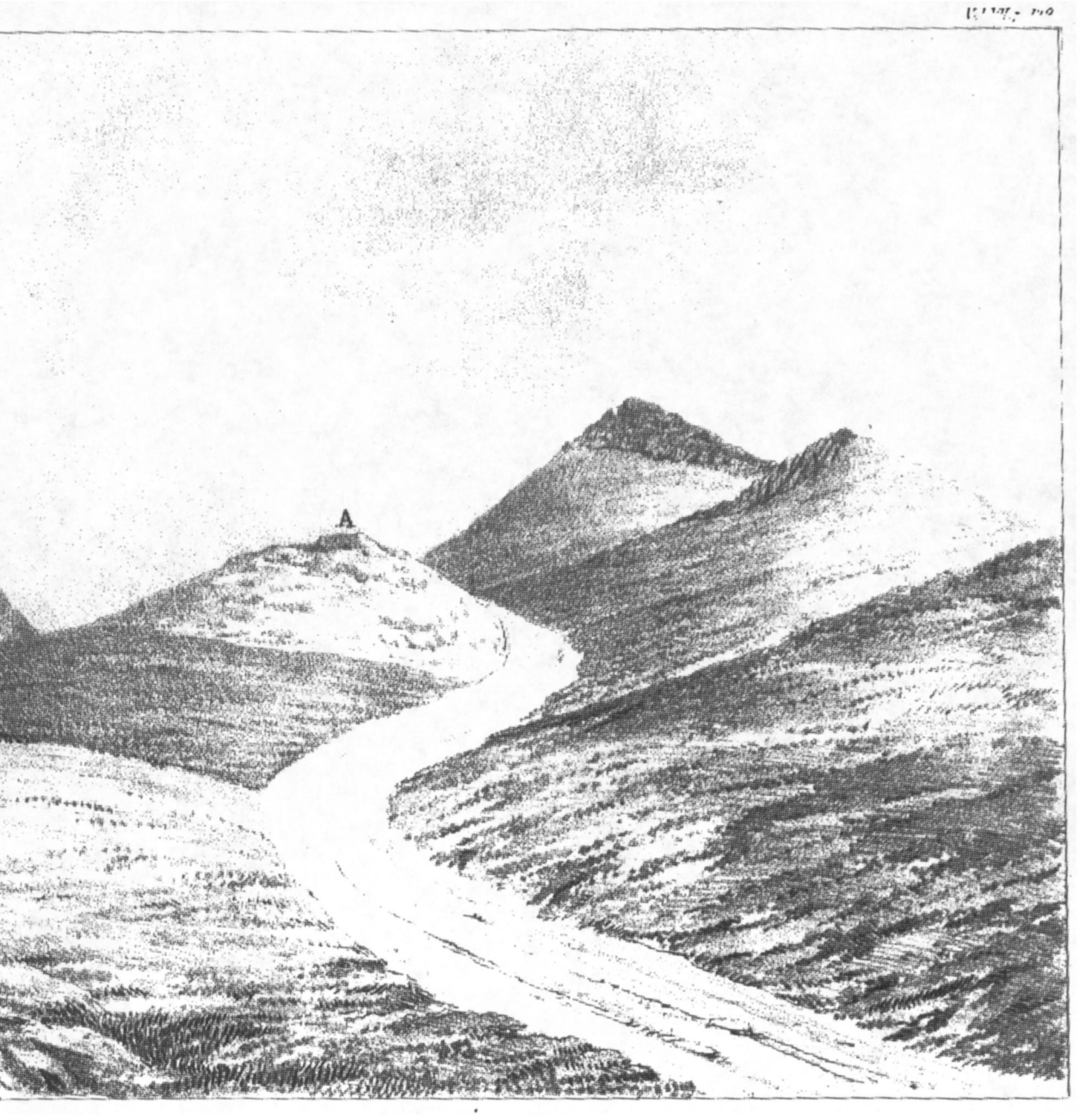


Mound of Scoriæ, eleven miles West from Bellary.

Drawn by Lieut^t E. Lawford, Madras Engineers.

(A. represents the Mound.)



Mound of Scoriæ, eleven miles West from Bellary.

Drawn by Lieut^t E. Lawford, Madras Engineers.

(A represents the Mound.)

ART. XI. — *Summary of the Geology of Southern India. By* CAPTAIN NEWBOLD, F.R.S., &c., *Assistant Commissioner for Kurnool.*

[*Continued from p.* 171.]

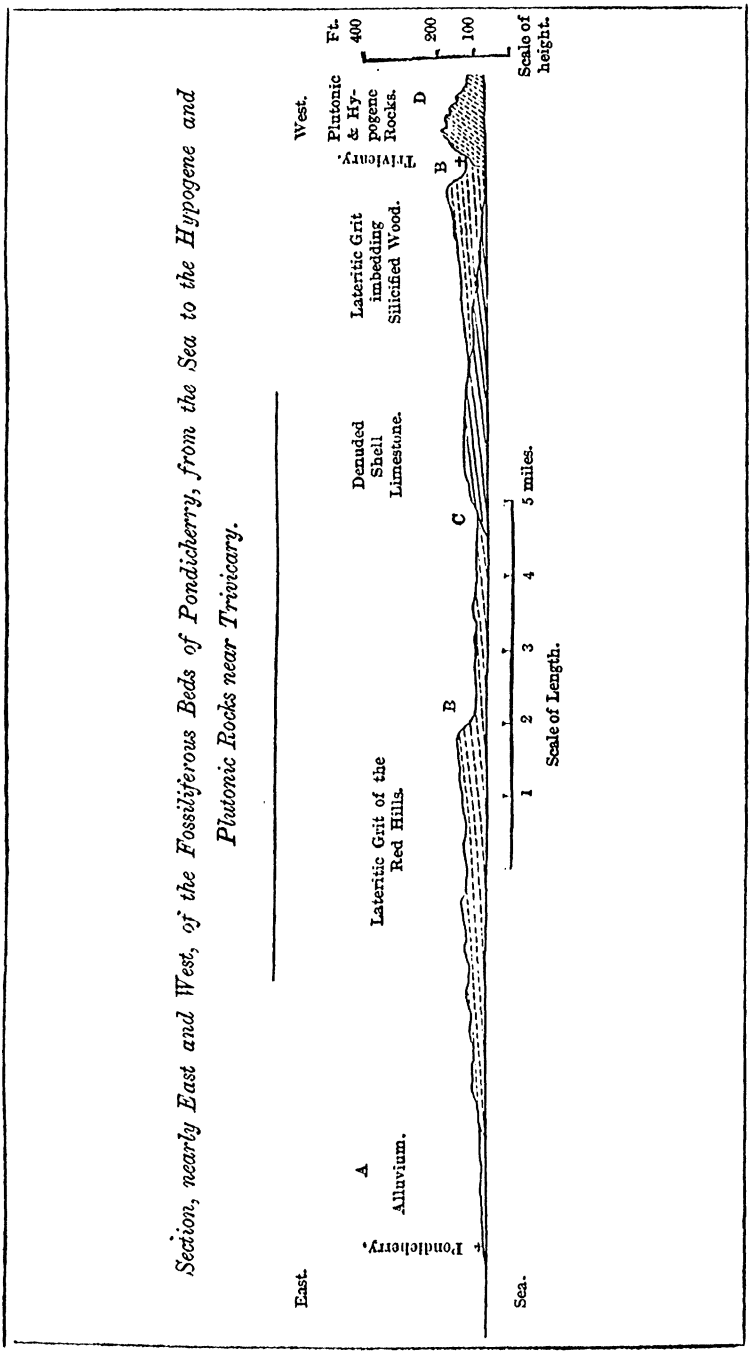
PART IV.

FOSSILIFEROUS LIMESTONE OF PONDICHERRY.

Geographical Position.—About nine miles inland of Pondicherry on the Coromandel coast, Lat. 11° 56′ N., are beds of limestone rising in gentle undulations, and running in a S.E. by E. direction, almost parallel with the coast, for a distance, as far as I was able to trace, of about four or five miles. Of these strata no detailed account had been published up to the date of my visit in March, 1840. They are seen to crop out near the villages of Sydapett, Carassoo, Coolypett, and Vurdavoor, from a superincumbent tertiary lateritic grit imbedding large quantities of silicified wood, and of which a description has been given by Lieutenant Warren: who has, however, overlooked the fossil limestone. The beds of the latter dip very slightly easterly. The greater part of the surface of the limestone is concealed by the soil and vegetation. A short distance further towards the west it is again covered by beds of the silicified wood deposit, and both are underlaid by plutonic and hypogene rocks, which crop out near the village of Trivicary, and form the western boundary of the fossiliferous beds. Rolled and angular fragments of the hypogene rocks are scattered here and there over the limestone, as well as fragments from the silicified wood beds, and from the limestone itself; the surface of the latter has evidently been exposed by the denudation of the superincumbent beds. It appears in surface-worn tables traversed by innumerable fissures.

Lithologic character.—It is usually of light brownish or grey colour; texture subcrystalline, graduating into earthy; tough under the hammer, and interstratified with argillaceous and ferruginous beds of a looser structure, which often abound with fossil shells. Some parts of the rock are so speckled with a dark-coloured sand as to resemble a *peperino*, though the nature of the sand, whether volcanic or not, cannot be safely pronounced upon. Other varieties are hard and compact enough to bear as fine a polish as many of our mountain limestones. It has been long used for the steps of doors, and in some of the pavements and old fortifications at Pondicherry; the remains of the old quarries are still to be traced though choked up by rubbish.

Section, nearly East and West, of the Fossiliferous Beds of Pondicherry, from the Sea to the Hypogene and Plutonic Rocks near Trivicary.



It will be observed in this section that, though the limestone has not been observed in contact with the hypogene and plutonic rocks, yet it is evident that it is of more recent origin, by the unconformability of the stratification.

The shells are, with few exceptions, pelagic: they occur distributed confusedly in the rock: the bivalves often vertical, and sometimes with their hinges uppermost. The valves of some are half opened: in others closed. Some have been deprived of one of their valves. Many have been compressed and flattened; and the exterior of a few exhibit distinct and beautiful impressions of smaller shells. The cavities of others again are filled with crystallized carbonate of lime; which may be received as an indication of the shell's being tenanted at the time of its entombment.

Since the period of my visit a large collection has been made of these fossils by Messrs. Cunliffe and Kaye, of the Madras Civil Service, most of which have been named as follows by Dr. McLelland; whose list, as it comprises all the fossils discovered by myself, and many other species besides, will be adhered to, (merely arranging them after Lamarck,) until a more minute examination is made of them in Europe, whither a collection has been already transmitted for the purpose of a careful comparative scrutiny and classification. This they well merit, considering these beds and those of Trichinopoly are almost the only marine deposits that occur over the great extent of Southern India.

Class Annelides,—Fam. *Serpulacea.*
Serpula recta.

Class Conchifera,—Fam. *Arcacea.*
Cucullæa crassatina (?) Desh.
Arca Cunliffei.
—— crassatina.
Nucula pectinata.

Fam. *Malleacea.*
Inoceramus.

Fam. *Ostracea.*
Ostrea trabeculata.
Gryphæa.

Class Mollusca,—Fam. *Calyptracea.*
Piliopsis plana. Same, or allied to a shell in the coal formation at Cherra.
——— rotunda.

Fam. *Colimacea.*
Bulimus Indicus.
——— Pondicerianus.

Fam. *Melaniana.*

Melania (?) imperfect.

Fam. *Peristomata.*

Paludina[1], allied to Paludina semicarinata, Brand. Desh. Coq. Fos. Pl. xv. Species of this genus existing in India and elsewhere.

Fam. *Neritacea.*

Nerita transversaria. Single specimen, imperfect.
Natica sulculosa.
Nerita speciosa (?)

Fam. *Scalariana.*

Scalaria annulata.
——— zonata.
——— tricostata.
——— bicostata.
——— Kayeii.

Fam. *Turbinacea.*

Trochus linearis.

Fam. *Canalifera.*

Murex levis.

Fam. *Orthoceritа.*

Baculites, compressed, tapering, and consisting of short joints. Margins unequal, both somewhat flattened.

Fam. *Nautilacea.*

Nautilus, three distinct species.

Fam. *Ammonacea.*

Ammonites.

Echini, fishes' teeth, and Hamites, corallines of the Turbinalia species, and others of a pyriform shape. There are also shells of the families Myaria, Nymphacea (Astarte), Cardiacea, Mytilacea, Pectinides, Ostracea (resembling Exogyra), Turbinacea (Turritella ?), Canalifera (Pyrula ?) Alatæ (Rostellaria?) Purpurifera (Buccinum ?) Convolutæ (Voluta), Ammonacea (Orbulites and Criocera-tites). A number of sulcated cylindrical bodies, not exceeding the thickness of a quill, of different lengths, but generally from two to three inches long, and in all cases broken off, are scattered in the substance of the rock. They resemble somewhat the spines of echinides. There was also found the vertebra of a fossil which Professor Owen pronounces to resemble that of Mososaurus.

Mr. Murchison states in his Anniversary Discourse, p. 136, there can be no doubt that these fossils belong to the Cretaceous system.

[1] It is much to be regretted that the only specimen in the collection is not sufficiently perfect to allow of the species to which it belongs being accurately determined; but the presence of a freshwater shell is important, as tending to show the deposit to have taken place near the mouth of a river, or in a basin alternately subject to salt and fresh-water.

Since then they have been ascertained by Professor Forbes to belong to the Lower Greensand, and Neocomian beds.

In a Paper by Mr. Kaye, in the Madras Journal of Literature and Science, for June, 1844, p. 151, that gentleman says, "In a former number of this Journal Lieutenant Newbold suggested that the fossiliferous beds of Pondicherry probably extended into the Verdachellum talook of South Arcot[1]. It was long before I was enabled to obtain any positive evidence of this fact; and it proves how little dependence can be placed on native evidence, that all inquiry among those who ought to have been best acquainted with local circumstances failed to elicit the required information. Accident, however, subsequently established the correctness of Lieutenant Newbold's views. * * * Mr. Murray, the Sub-Collector of South Arcot, in the course of a ride, about six or seven miles from Verdachellum, observed that the surface of the rock, by the side of the road, was marked with shells; and was kind enough to send me a few specimens, chiefly pectens." Mr. Kaye subsequently visited the locality himself: the fossiliferous limestone he found to appear first at the bottom of a valley near the village of Paroor, seven miles from Verdachellum, and forty from the coast: the high ground between it and Verdachellum consists of the red sand (resembling the red sandstone of Pondicherry,) in which was found a fragment of silicified wood; but the limestone rises into small hills on the opposite side of the valley. Mr. Kaye found in this limestone, Rostellaria, Arca, Pecten, Exogyra, Cardium, Lima, Terebratula, and other shells, which identify it, he thinks, completely with the Ootatoor beds near Trichinopoly, which will be described presently; and in addition a large number of Ammonites, of three or four different species, dissimilar to those of the Pondicherry beds: also portions of Nautili, and a Spatangus, similar to those of Pondicherry. Mr. Cunliffe, Mr. Kaye's zealous coadjutor in these most interesting discoveries, states that the genus Cidaris was numerous at Verdachellum, or rather, Paroor, though, as yet, undiscovered in the Pondicherry beds; and the Baculites of the latter were wanting at Paroor: and not a single chambered shell, save the cast of a single chamber of a large Ammonite, has been found in the Trichinopoly deposit at Ootatoor. Among the Verdachellum fossils were the bones of an *ophiura*, or star fish, which Professor Forbes pronounced to be the best preserved specimen he ever saw from the cretaceous beds.

Too much praise cannot be attached to the indefatigable exertions, zeal, and acumen of Messrs. Kaye and Cunliffe, who have thus

[1] It is probable that these fossiliferous beds may be traced still further south.—T. J. N.

established the interesting fact of the existence of cretaceous rocks in Southern India by a series perhaps of the most beautifully preserved fossils that were ever laid before the geological world, embracing many new forms, and some of Cypræa, Cerithium, &c., which were supposed to be peculiar to tertiary strata, but were doubtlessly formed in a cretaceous sea.

The Neufchatel beds, *Terrain Néocomien*, and the Neocomian strata of the Crimea, have been referred to the Wealden of British geologists; but by Mr. Murchison they are considered to be the equivalent of the lowest green sand of England, and of the *Hils-thon* of Römer in Hanover. The fossils of the Pondicherry beds will probably throw additional light on this *quæstio vexata*.

Trichinopoly Fossil Limestone.

About seventy-eight miles inland from the Bay of Bengal, in the vicinity of Trichinopoly, Lat. 10° 52′ N., and Long. 78° 46′ E., beds of a marine limestone occur, the geognostic position of which has not hitherto been described: though it is supposed they rest immediately on the plutonic and hypogene rocks which surround it.

The fossils brought thence are pelagic, comprising members of the families Serpulacea, Nymphacea (Tellina? Venus?), Cardiacea, and Arcacea, some of which are identical with those of the Pondicherry beds; also, Scalarias, Rostellarias and Turritellas. No Baculites, Hamites, or Nautili have hitherto been discovered, or other shells sufficiently characteristic to identify this deposit with the Pondicherry beds, from which they are distant about 100 miles to the S.W. The cast of part of an Ammonite, and a piece of silicified wood, resembling that of the lateritic deposit covering the marine limestone of Pondicherry, pierced by Teredines, have been found on the Trichinopoly beds.

The imbedding limestone, though bearing a general resemblance to that of Pondicherry, is usually less crystalline, looser in texture, and darker in colour than that of Pondicherry: and the organic remains in a better state of preservation, and more numerous.

Until more information be obtained, the geognostic place here assigned to the Trichinopoly beds must be merely considered as provisional.

PART V.

Fresh-water Limestones and Cherts.

We are now arrived at deposits which I have little hesitation in referring to the tertiary epoch. Although the deficiency of rocks of this age, and of the secondary period, forms a remarkable feature in the geology of Southern India, yet that of the former is not so great as has hitherto been generally supposed.

Nirmul Beds.—In the route from Hydrabad towards Nagpore, on the north bank of the Godavery, among the Nirmul Hills, and thence across the Wurda to Hingan-ghaut beyond the limits of our area, Mr. Malcolmson discovered detached beds of chert and limestone, containing shells, the general character of which Mr. Lonsdale considers to be that of fresh-water. The fossils were first found at Munoor, and between this village and Hutnoor, which is near the top of the Mucklegundi Ghaut, and in different parts of this pass leading into the valley of Berar. Mr. Malcolmson describes[1] the bed in which they were first observed to be a band of a singular quartz rock, projecting about two feet from the surface, half-way up the escarpment of the principal mountain, ascending the steep pass leading up the south side of the Nirmul Hills, and which is composed of concentric nodular basalt imbedded in a soft greenish wacké.

The quartz rock is remarkably scabrous, of various shades of white and red, and has cavities on its surface covered with fine silky crystals. Mr. Malcolmson observes, that it had every appearance of having been forced into its present position, when the basalt covered and partially melted the bed to which it belonged. Many fragments of this rock were found below with the shells; and it was again met with, together with the same and other fossils, imbedded in basalt, near Hutnoor. The specific gravity of this rock is 2·473, and some of the specimens effervesced feebly in acids, a portion of lime being dissolved.

The rock in which the fossils occur varies in different places: some of the finest specimens were obtained from a red chert with scabrous surface, having silicified shells distributed throughout its substance, or projecting from its surface. Besides testacea, this red chert contained small portions of silicified wood, and what Mr. Malcolmson considered, though he states at the same time that the specimens were too imperfect to admit of any certainty, to be the fragment of a bone, and of the tooth of a mammiferous animal.

[1] Geol. Trans., Vol. V., Second Series, pp. 549, 550.

The finest Unios occur in a beautiful grey chert, imbedded in the basalt, or resting immediately on it. Some parts of the rock exhibit a mixture of sand, clay, and fragments of shells, of very moderate hardness, but the greater part consists of chert, the materials of which are occasionally arranged in a beautiful light blue enamel-like substance, around irregular cavities containing crystals of purple quartz. Some portions also exhibit a minute vesicular structure. Some are composed of a tough white clayey stone so soft as to stain the fingers: these contained Physæ, Paludinæ, and Limneæ, mostly converted into calcedony; but others retained their original structure, and effervesced with acids. Portions of charred vegetable matter, resembling small fragments of grasses and weeds, occur in these and in the harder cherts. Other specimens are composed of a greenish-blue crystalline mass resembling an ore of copper, (but it is of low specific gravity, and contains no trace of that metal,) and the imbedded shells are converted into the most beautiful crystalline quartz, retaining the form of every convolution of the Physæ and Paludinæ. Masses of a hard coarse chert consist almost entirely of Gyrogonites, but contain many of the same Physæ and Paludinæ. This rock appears to have formed beds of about half a foot in thickness; but it was not discovered *in situ*. A stratified rock was however found in the vicinity, consisting of a compact whitish chert, which contained Paludinæ and the finest specimens of Gyrogonites. Night prevented the connexions of this rock from being determined; the strata were, however, ascertained to be of considerable extent, and to be much buried in the soil: there were also numerous fragments of a siliceous rock, partly converted into black bituminous flint, or a coarse quartzose rock, partially altered into calcedony, by which most of the shales were also replaced.

After descending the second terrace a bed of white horizontally-stratified limestone, almost wholly composed of large bivalved Unios (named Deccanensis by Mr. J. de Carle Sowerby, 4 to 8 of description), is met with. The shells are not in very good preservation. Their edges, decomposing more slowly than the cement, jut out in relief. Hence the name of Mucklegundi, or *Bukre ke paiw ka putthur*, "sheep's feet stone," applied by natives to the pass and the rock, from the resemblance the shells are thought to possess to the impressions of the feet of these animals in clay. The Unios found in this bed have been identified with those in the chert at Munoor. It also contains a species not yet discovered elsewhere, viz., the Unio tumida? (11 and 12). At the bottom of the little cliff, where the granite is seen to underlie the fossils, very perfect Melaniæ were found in a fragment of a compact argillo-calcareous stone, identical with those in the lime-

stone. The shells are fossilized by compact limestone, imbedded in a matrix consisting of calcareous matter mixed with small fragments of granite, and of a friable, grey, cellular substance resembling ashes, which occurs in situations where the limestone becomes concealed in the basalt, and is apparently imbedded in both rocks. The thickness of this fresh-water limestone bed, in one place where it is intersected by a torrent, is twelve feet, and it rests directly on red granite. The cherts all rest on, or have been entangled in the basalt, and are doubtless nothing more than the metamorphosed limestone; even the calcareous walls of the shells have been converted into silex. The basalt comprising the higher portions of the Nirmul Hills rests on this granite.

I have already transgressed my limits in tracing the course northerly of this interesting series of deposits, which were, probably, once continuous, until broken up, altered, and scattered by that prodigious eruption of trap which covers the greater portion of the Deccan: but I cannot refrain from quoting Mr. Malcolmson's interesting account of the Chicknee and Hingan-ghaut deposits which lie between the Mucklegundi Pass and Nagpore, separated by tracts of granite, blue limestone and sandstone, resembling those of Cuddapah and basalt: inasmuch as a brief description of the manner in which these fresh-water patches are distributed over the great overlying trap, will conduce more than anything else to a true conception of their origin.

Near Chicknee, the schist (viz., the red schist found above the limestone south of the Urjunah hot springs, and in various places of the diamond districts of the south,) rises slightly towards a basaltic ridge, in which the fossiliferous chert is likewise imbedded. The fossils occur on the surface, or are imbedded in nodular basalt, over several miles, being found in blocks of indurated clay, chert, and flinty slate. The appearance of the indurated clay is the same as in some of the specimens from the Sichel (Nirmul) Hills, but the clay is harder, full of cavities, and, in some cases, passes into perfect chert, or has waved lines of quartz or opalized matter diffused through the substance of the mass. Many Physæ, Paludinæ, and a few Limneæ, of the same species as those already noticed, are found in this indurated clay, or imperfect chert. Some of them are entirely converted into calcedony; others have the lime replaced by quartz, which is finely crystallized and covers the surface of the convolutions; or the columella only is preserved, passing across an empty cast of the shell. In some cases, however, the structure of the fossil is unaltered, and it effervesces in acids.

Flinty slate without organic remains occurs in the neighbourhood of these amorphous masses, and many fragments of the same kind, containing large compressed bivalves, are scattered about. In one block of this kind, portions of palm wood mineralized by black flint, intersected by fine veins of a light blue opal [of the same kind as occurs in some of the specimens of fossil wood from Antigua, by Mr. Stokes], was found associated with compressed very thick bivalve shells, probably referable to the same species as those of Munoor. At Hingan-ghaut, a few miles further to the north, considerable fragments of silicified palms and other plants were found in a black chert lying on the basalt, and similar masses, but without fossils, were imbedded in it. No organic remains were met with between this place and Nagpoor, the whole of the country being covered with a rich black soil, from which insulated basaltic hills with flattened summits rise abruptly.

In examining with the microscope sections of some of the silicified wood from the chert of Hingan-ghaut, one appeared to Mr. Malcolmson to be bone, which was examined by Professor Owen, who gives the following note:—"A section of this fossil was prepared sufficiently thin to allow of its being examined by transmitted light under a high magnifying power, when it was found to possess the structure characteristic of bone. Sections of 'Haversian Canals,' with their concentric lines, were everywhere present, interspersed with numerous Purkingian cells, or corpuscules: the size and disposition of these characteristic parts of the osseous structure agreed with those of the bones of the mammalia. It was highly satisfactory to find the microscopic test as available in demonstrating the presence of bone, when ordinary characters and the unassisted eye would have left the matter doubtful, as it is in reference to the determination of the teeth."

The silicified wood of these deposits appears to be chiefly palms; no specimens of dicotyledons are mentioned. The shells and charæ have been engraved and described by Mr. J. de Carle Sowerby as follows:—

1. *Chara Malcolmsonii.*—Oblong, spheroidal, with ten ribs; three of the ribs are produced at the apex. Natural size, and magnified.

This capsule is composed of five tubes, each of which is curled twice round. The figures represent a cast of the interior, the tubes being split down, and the outer halves broken away and left in the chert. The specimens are silicified, and constitute almost the entire mass of the rock, in which they occur associated with Physæ and Paludinæ.

2. *Cypris cylindrica.*—Twice as wide as long, almost cylindrical;

front very slightly concave; the outer surface, which is very rarely obtained, is punctured.

3. *Cypris subglobosa.* — Subglobose, triangular, inflated; front concave.

The outer surface of this crustacean is punctured as in *C. cylindrica.*

Both species occur abundantly in grey chert, with the *Unio Deccanensis* and other shells; and in various specimens of chert and indurated clay, containing *Gyrogonites, Paludinæ, Physæ,* and *Limneæ,* from the Sichel (Nirmul) Hills. The fossils are converted into calcedony.

4 to 10.—*Unio Deccanensis.*—Transversely oblong, rather compressed; margin internally waved; shell very thick; surface finely striated. Fig. 6 is in limestone from the northern descent of the Sichel (Nirmul) Hills; the others are in chert from Munoor. Natural size.

This species has often a ridge, which bounds the posterior portion, and is variable in size and elevation. It is most conspicuous in the limestone specimen, fig. 6, and in a cast in chert from Munoor, fig. 7. Fig. 8 is possibly a very young individual, before the margin had assumed its wavy form. Fig. 9 is from a part of a group of many individuals of nearly one size, badly preserved in the same limestone as fig. 6; but as they are generally oval, and do not show a waved margin, they may belong, as well as fig. 10, which is in grey chert from Munoor, to a species distinct from *Unio Deccanensis.* Some flattened specimens from this limestone are two and a half inches broad.

11 and 12. *Unio tumida.*—Transversely obovate, smooth, gibbose; posterior extremity rather pointed; beaks near the anterior rounded extremity. Natural size.

The section of the two valves united is regularly heart-shaped. The shell is rather thin, and it has something of the contour of *Cyrena.* It occurs in the same limestone with fig. 6, and the substance of the shell is replaced by calcareous spar, which cannot be broken so as to show the hinge.

13. *Limnea subulata.*—Subulate, elongated, smooth; spire equal in length to the body; whorls five. In a nearly white, soft, siliceous stone, from Munoor and Chicknee. Natural size.

14, 15 and 16. *Physa Prinsepii* (so named after the lamented J. Prinsep).—Ovate, rather elongated, smooth, spire short; body whorl largest upward. Fig. 16 in a soft siliceous stone from Munoor. Fig. 14 in chert from Munoor, and fig. 15 in chert from Chicknee; the drawing represents the shell as wider than it is. Many of the

specimens are crushed. The largest, fig. 15, are two and a half inches long and upwards of an inch broad. Natural size.

17 to 19. *Melania quadri-lineata.*—Subulate, whorls about eight, with four striæ upon each; aperture nearly round. Fig. 17, in grey limestone from the same locality as 6 and 11. Fig. 18, in softish chert from Chicknee, associated with *Physa Prinsepii.* Fig. 19, in fine reddish grey chert, protruding from basalt near Munoor, appears rather shorter in form than the others, but the spire is not perfectly exposed nor entire. Natural size.

20 to 23. *Paludina Deccanensis.*—Short, conical, pointed, rounded at the base; whorls five or six, slightly convex, aperture round. Fig. 21 is in chert from Munoor; and figs. 20 and 22 in indurated clay from between Munoor and Hutnoor, the cavity of the shells being filled with calcedony. The young shell has a slight carina, shown in fig. 20. Fig. 23 appears to be a crushed specimen; it is in laminated, indurated clay, Munoor. This shell occurs, with *Physa Prinsepii,* in a beautiful green siliceous mineral at Munoor, at Chicknee, and at the bottom of the Nirmul Pass. All the specimens natural size.

These shells all belong to fresh-water *genera,* and to species which have not yet been discovered recent. The charæ, too, have not yet been found in the fresh-waters of India.

Similar beds of limestone and chert are scattered over the whole of the overlying trap region, and on its borders, in thin and circumscribed patches, and separated by distances often considerable, but imbedding similar fresh-water shells. Voysey[1] observed a stratum of earthy clay of different degrees of induration, twenty yards in length, and about two feet thick, containing a great number of entire and broken shells.

Near the summit of the table land of Jillan, in a pass ascending from the valley of the Taptee, or Berar, which separates the Gawilghur trap ranges from those of Nirmul, or Sichel, the shells are much compressed, and their structure seemed to Voysey to have been depressed by an overlying mass, fifteen feet thick, of the nodular basalt or wacké on which, too, this shell deposit rests. The vertical fissures, so remarkable in trap rocks, are prolonged from both the upper and lower rocks into the shelly stratum, although there is no intermixture of substance. The casts and fragments of the shells resemble those of the Paludinæ and other shells of the Nirmul Hills already described. Voysey discovered shells in an indurated fossiliferous clay near Nirmul and others in a siliceous rock containing lime,

[1] Asiatic Researches, Vol. XVIII., page 192, and Journal of Asiatic Society of Bengal, Vol. II., p. 304.

resembling in every respect the fossiliferous cherts of the Nirmul Hills, and like them imbedded in basalt, on the insulated hills of Medcondah and Shivalingapah, which rest on granite, south of the Godavery, near the south border of the great overlying trap, and also in the hills of Bicknoor-pett and Nugger.

Mr. Malcolmson[1] found in a specimen of the chert from Medcondah, in the Museum of the Geological Society, a Gyrogonite of the same kind as those of Nirmul, and halves of a species of Cypris associated with shales.

Dr. Spilsbury found, eighteen miles from Jubbulpoor, in the valley of the Nerbudda, blocks of "indurated clay," associated with the trap, containing casts of fossil shells, for the most part siliceous, and resembling those found by Dr. Voysey in the Gawilghur range on this side the valley. At Saugor, nearly one hundred miles to the north-west, reversed shells, stated to be exactly the same as those of Jubbulpoor, were discovered by Dr. Spry in a bed of limestone covered by seventeen feet of basalt, and resting on a coarse siliceous grit, underlying which the basalt again occurs. Fine specimens of silicified palm wood occur in the vicinity, as well as fossil bones of mammalia in a limestone capped by basalt. The drawings of the shells, Mr. Malcolmson observes, differ a little from each other, but the fossils are stated to be the same; and, as far as Mr. Sowerby could judge, they do not differ from the *Physa Prinsepii*. The similarity was more obvious in other specimens left in India.

South of the Nerbudda, fossils are again met with in the mountainous country north of the sources of the Taptee, at a place called Jirpah, near to which trap hills have broken through the sandstone.

Hydrabad Beds.—Between Beder and Hydrabad, on the south edge of the overlying trap, I found, in 1839, loose blocks of a greyish white limestone imbedding a few fragments of univalve and bivalve shells in so comminuted a state as not to be recognizable. The limestone in lithologic character closely resembles some varieties of the fresh-water limestone of Nirmul, and is equally broken up by the overlying trap. The blocks were partially converted into chert, and half buried in the soil covering the trap on which they rested. Thence, following the edge of the overlying trap in a south-westerly direction towards Bijapore, as it skirts the plutonic and hypogene rocks of the south to the valley of the Bima, between Muctul and Gulberga, another bed of fresh-water limestone occurs, extending from the vicinity of Koolkoondah northerly to Digaye, where it rests on blue non-fossiliferous limestone, which disappears under a great coulée of trap on the

[1] Transactions Geological Society, Vol. V., Second Series, pp. 570 and 571.

opposite bank of the Bima, between it and Gulberga. The specimens brought me by my friend Captain Wyndham contained only one description of shell, the *Paludina Deccanensis*. Still further to the west and near Ingliswara large blocks of the whitish grey siliceous limestone occur entangled in, and broken up by the trap, but I did not find they contained any fossils. It has in many situations been converted into chert and jasper, it is harsh and trachytic to the feel, and has an irregular sparry fracture; it usually appears on the sides and summits of hills, projecting in rough scabrous masses from the surface, easily distinguished from the dark trap. A similar limestone is noticed by Captain Coulthard[1], on the north-east side of the great trap region.

The only other described deposit of fresh-water shells is that about five miles south-west of Puddpungallee, which is ten miles south-west from Rajahmundry on the Godavery, a little above its delta. They occur in limestone, both underlain and capped by trap, evidently an outlier of the continuous trap formation so often alluded to in the account of these beds. Here, however, the deposit must have been in an estuary, or lake communicating with the sea; since Dr. Benza states[2] that among the *Limas* and *Melaniæ* he found oysters. They occur in a hill elevated about 300 or 400 feet above the plain in which it is situated, about fifty miles inland from the present coast line. The base of this hill as well as of the plain is of a red conglomerate sandstone, (evidently identical with the diamond conglomerates of Malavelly, Cuddapah, &c.,) resting on a grey non-fossiliferous limestone, seen in a lower situation nearer the Godavery; over the conglomerate is a layer of wacké with jasper, which continues about midway up the hill, where it is succeeded by a thick bed of the shell limestone capped by wacké and basalt. According to Dr. Benza, the limestone protrudes in a little ridge, a foot or two raised above the side of the declivity, running some hundred yards east and west, and cutting the hill in a direction parallel to its base, appearing to be vertically situated. The outgoings of this bed are tufaceous, as well as the surface of the implanted blocks all around it, and in which the fossil shells were clearly distinguishable; but when fractured deep exhibits a compact texture, a whitish colour verging to yellow, and a fracture semi-conchoidal and glimmering, on account of the numerous crystals of carbonate of lime, into which all the fossil shells are converted. It sometimes abounds with small cavities lined with calc-spar, and exhibiting only the impression of the shells, their substance having been

[1] Asiatic Researches, Vol. XVIII., Part I., p. 59.

[2] Madras Journal of Literature and Science for January, 1837, pp. 50, 51.

absorbed. Loose blocks of the shell limestone are scattered about the nullahs and on the declivity of the hill; others implanted in the soil.

The basalt is both compact and vesicular; sometimes approaching amygdaloid, the cavities often lined with calc-spar; the wacké underlying the limestone is veined with jasper, occurring also in beds and thin ramifications, which, in consequence of the wacké's easily weathering, are scattered about the surface. These jaspers and wackés exactly resemble those of the overlying trap. Most of the shells have evidently undergone violence, or compression, being fractured, and many of them reduced to small fragments. Some of the masses of the limestone are entirely composed of shell, converted into brilliant and sparry crystals of carbonate of lime.

The top of the hill forms a kind of table land capped with globular basalt decomposing in concentric layers, and extends apparently a few miles eastwardly. The loftier hills to the east of this, according to General Cullen, are of a similar formation; and as they present deeper nullahs, vertical escarpments and precipices, better opportunities would be afforded of observing the geological position of the strata. But of this interesting range no published account has been yet given. General Cullen has the merit of having discovered this deposit.

PART VI.

Laterite.

Geographical Position and Extent.—Laterite occupies a larger portion of the superficies of Southern India than has been commonly supposed. The western coast is almost continuously covered by a sheet of this rock, extending, usually, inland to the very base of the Ghauts; and from the south of Bombay to Cape Comorin. Thence along the east or Coromandel coast it occurs in detached beds; the most considerable of which are those composing the Red Hills near Madras, Nellore, vicinity of Rajahmundry, Samulcotta, and into Cuttack.

It is found capping the loftiest summits of the Eastern and Western Ghauts; and of some of the isolated peaks on the intervening table lands. On those of the northerly parts of our area it appears in more continuous, and extensive sheets; often forming long low ranges of flat-topped hills, resembling in contour those of the horizontal sandstone and overlying trap formations. The laterite bed of Beder, in Lat. 17° 55′ N., and Long. 77° 34′ E., is about twenty-eight miles

long from W.N.W. to E.S.E.; and twenty-two miles broad. It forms a table land, elevated, according to Voysey, at 2359 feet above the sea's level; and terminating to the north in precipitous façades, forming salient and re-entering angles, on the right bank of the Monjera. The average thickness of the bed is about 100 feet: its maximum 200 feet.

The Calliany Bed, about forty miles westward from that of Beder, is of still greater extent; and the intervening space has all the appearance of having been covered with a continuous bed stripped off by denudation, and exposing the subjacent trap, amygdaloid, and wacké. It extends southerly to the confines of the valley of the Bhima, about sixteen miles; and is upwards of forty miles in length, running nearly east by south. This sheet is not quite continuous; the laterite ranges, which are low and flat-topped, being separated by narrow valleys with flat bottoms based on trap.

Near Ingleswara, in the South Mahratta country, are some laterite ranges, the extent of which has not been exactly ascertained.

Farther south are beds of smaller extent on the table land around Kulladghi, Bagulcota, and Belgaum; and still further south at Bangalore and Bunwassi in Mysore. That at Bangalore is supposed to extend northerly towards the vicinity of Nundidroog. Laterite occurs also in scattered patches over the country below the high table lands of Mysore, south of the Salem break, throughout Salem, Coimbatoor, South Arcot, the Carnatic, Tanjore, and Madura; and covers a considerable portion of Travancore.

It is also found capping, in beds of considerable thickness, both the summits of continuous ranges,—such as those of Sondoor, Bellary, Kuppulgode, south of Cuddapah, &c., and of isolated peaks,—the Nilgherry and Coorg Mountains. It occurs in more circumscribed and detached patches on the Eastern Ghaut line, and the beds are seldom continuous on broken ranges, as in the vicinity of Samulcotta, Chicacole, Bunlipatam, and in various localities in Goomsur[1].

In the hilly region bounding the Mogulbundi to the westward, from the Chilka Lake to the Subaurekha, the laterite lies in beds of considerable thickness on the feet of the granite hills, often advancing out for a distance of ten or fifteen miles into the plains, where it forms gently swelling rocky elevations, but never rises into hills; sometimes it is disposed in the manner of flat terraces of considerable dimensions, which look as if they had been constructed with much labour and skill. The granite appears to burst through an immense bed of the laterite rising abruptly at a considerable angle. This singular rock,

[1] Stirling's Account of Cuttack, pp. 15 and 16.

unknown in Europe, is not confined to the Eastern peninsula of India, but extends as a fringe, with more or less interruption, to the shores of Birma, Malacca, Siam, capping many of the granitic mountains in the interior. I have seen it on the coast of Sumatra, and on many of the islets in the Straits of Malacca, invariably occupying the same overlying position. It occurs also in Malwa, many parts of Bengal, and in Ceylon.

Physical aspect.—Lateritic districts have frequently been reproached for the sterile aspect they usually present. This arises chiefly from the too ferruginous or siliceous character of the rock, its porous structure, which does not admit of retention of moisture, and the property it possesses of hardening on exposure to the atmosphere. The soils formed by the weathering of the soft and argillaceous varieties of laterite are fertile, and produce abundant crops of rice, and of the dry grains that ripen in the early part of the season. Hills of laterite are usually distinguished, as before observed, by their long, low, flat-topped character, assimilating those of the trap and horizontal sandstone formations. The lands they support are, however, not so much furrowed as those of the sandstone by water channels, a circumstance ascribable to the drainage passing rapidly off through the pores of the rock. When capping detached rocks, the laterite usually imparts to the whole mass a dome-shaped or mammiform outline, or that of a truncated cone.

On the surface of table lands it is spread out in sheets, varying from a few inches to about 250 feet in thickness, terminating on one or two sides in mural escarpments.

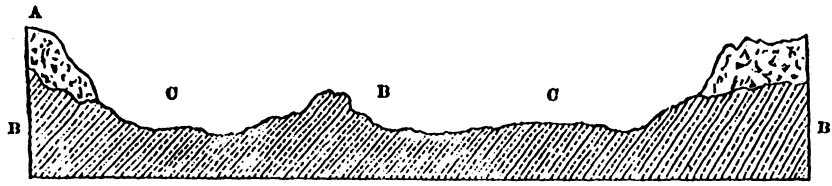
Immense detached blocks, generally of a cuboidal shape, are often seen occurring on the flanks of the Western Ghauts, and on the southern slopes of the Sondur hills, often separated and dislodged; the valleys intervening between ranges of laterite hills are generally winding like those formed by the course of a stream, and flat-bottomed; particularly in districts where it overlies the newer trap.

From a general survey of its localities and position on the superfices of Southern India, it seems probable that the laterite extended over it far more continuously than at present; and that it owes much of its frequently insulated position to denudation,—the vestiges of which are clearly traceable in extensive tracts of lateritic gravel and debris, which are often re-aggregated; and it requires great care and observation not to confound such deposits with the true laterite beds from which they have been derived. As the land slowly emerged from the waters of the ocean, the process of denudation went on hand in hand with that of upheaval in laying bare the subjacent plutonic,

hypogene, and trappean rocks. From the contour of the peninsula, and its general slope to the east, it is evident that the Western Ghauts must have first appeared above the surface, and the land to the east of this great chain by subsequent gradual efforts; the Coromandel, or eastern coast, probably appearing last. Hence the continuity of the lateritic zone is much more interrupted on this than on the western coast, where the elevation was at a much greater angle; as the course of the retiring waters of denudation must have followed the easterly direction of the present great lines of drainage.

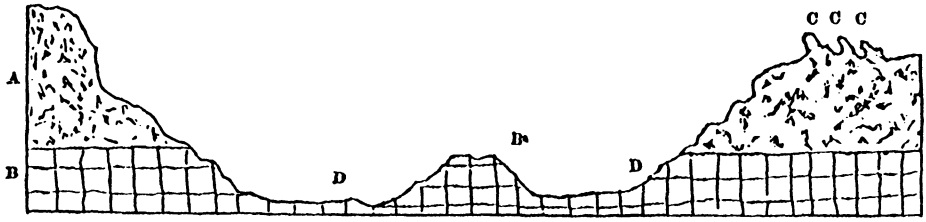
Natural sections often remind one forcibly of that striking instance of denudation of the red sandstone on the north-west coast of Ross-shire, given by McCulloch[1]. The following section, No. 1, is taken on the western coast of India, between Honawer and Sedasheger. No. 2 is from the cliffs of Beder, on the table land of the Deccan.

No. 1.



A A Beds of laterite once continuous, capping B B.
B B B Gneiss and hornblende schist.
C C Denuded space.

No. 2.



A A are cliffs of laterite from 90 feet to 120 feet high, once continuous.
B B Overlying trap and amygdaloid.
C C C Hard ferruginous masses of laterite: though evidently much water-worn, they have successfully maintained their position against the transporting effects of the stream, which not only stripped off the laterite, and denuded the subjacent trap, but excavated the latter to the depth of many feet, leaving the hard mass of trap B* in the centre, and the valley of denudation and excavation D D.

The valley runs east by south, and over the plain at its eastern extremity are scattered the hard nodular fragments of the stripped-off laterite from D D, mingled with *regur* and the recent alluvium of the laterite rocks. No causes now in action could have effected these denudations.

[1] Western Isles, Vol. II., page 93, plate 31, fig. 4.

Stratification and Dip.—Laterite usually occurs in tabular masses, which like the thick-bedded sandstones present no appearance of stratification. Where, however, the laterite loses its cellular structure, and takes the character of a sandstone or conglomerate, its true bedded structure is obvious. I have never seen its dip vary much from the horizontal.

Lithologic Character.—This rock derives its name *Lateritis*, (bestowed on it by Francis Buchanan,) from its being cut into the form of bricks, and used as such by the natives, who term it often in their own dialects the brick-stone. Buchanan[1] identifies it with the *Argilla lapidea* of Wallerius.

The laterite varies much in structure and composition; but, generally speaking, it presents a reddish brown, or brick coloured, tubular, and cellular clay, more or less indurated, passing on the one hand into a hard, compact, jaspideous rock, and on the other into loosely aggregated grits or sandstones, as at Beypoor near Calicut, Pondicherry, &c., and into red sectile clays, red and yellow ochre, and white porcelain earth, plum-blue, red, purplish, and variegated lithomarges. Sometimes it presents the character of a conglomerate containing fragments of quartz, the plutonic, hypogene, and sandstone rocks, and nodules of iron ore derived from them, all imbedded in a ferruginous clay.

The cavities are both vesicular, tubular, and sinuous; sometimes empty, but, in the lower portions of the rock, usually filled, or partially filled with the earths and clays above-mentioned, or a siliceous and argillaceous dust often stained by oxide of iron. A species of black bole, carbonized wood, and carbonate of lime, sometimes occur, but rarely, in these cavities. Minute drusy crystals of quartz not uncommonly line the interior.

The walls separating the cavities are composed of an argillo-siliceous paste, often strongly impregnated with iron, and frequently imbedding gritty particles of quartz. The oxide of iron prevails, sometimes to such an extent as to approximate a true ore of iron, and the nodules are often separated and smelted by the natives in preference to using the magnetic iron ore, which is more difficult to reduce, from its greater purity. When the whole mass is charged with iron, and very vesicular, (not unfrequently the case,) it might easily be mistaken for iron slag. The colour of the *parietes* separating the tubes and cells, which in the less ferruginous varieties is a light brick red or purple, changes into a liver brown; having externally a vitri-

[1] Journey through Mysore, Canara, and Malabar, Vol. II., pp. 436 and 440.

fied or glazed aspect; while the surface of the interior cavities puts on iridescent hues. The walls of these cells are sometimes distinctly laminated.

The specific gravity varies, as may be supposed from what has just been said. Many average specimens of the laterite of the Malabar coast I found to range between 2· and 3·2; that of the laterite of the Malay peninsula was found by Dr. Ward to be 2·536.

Before the blow-pipe the walls of the cavities melted into a black shining glass powerfully attracted by the magnet. The brown paste and ochreous dust contained in the cells did not fuse, but were converted into a cineritious slag less powerfully attracted, whilst the reddish and purplish portions hardened and remained almost unchanged beyond exhibiting scattered minute magnetic globules, having a dark metallic lustre.

The air exposed surfaces of laterite, as previously remarked, are usually hard, and have a glazed aspect, and the cavities are more empty than those in the lower portion. A few inches or more below the surface the rock becomes softer, and eventually, as it descends, so sectile as to be easily cut by the native spades, but hardens after exposure to the atmosphere. Hence it is used largely as a building stone in the districts where it prevails, and to repair roads. From its little liability to splinter and weather, (time appears to harden it,) it is a good material in fortifications; for which, and in the construction of their early churches, it has been largely used by the Portuguese on the western coast, and in their settlements to the eastward. The Arcaded Inquisition at Goa was built of it, and the old fortress of Malacca. The angles of the blocks of laterite in the remaining portions of these massive structures are as sharp and perfect as though the block had been separated from the rock but yesterday, although upwards of three centuries have elapsed.

The accumulation of the clays and lithomargic earths in the lower portions of the rock, which absorb some of the moisture percolating from above, renders the mass soft and sectile. These earths, doubtless, existed once in the upper cavities of the rock, from which they have been gradually removed to the lower strata by the downward action of the water of the monsoon rains. They accumulate at various depths from the surface and form impervious beds, on the depressions of which the water collects, forming the reservoirs of the springs we often see oozing, as at Beder, and many localities on the Malabar coast, from the bases and sides of lateritic hills and cliffs. Some of the tubes and cavities are *culs de sac*, and do not part with their contents, but the generality have communication with those below them,

either directly or indirectly. The downward action of the water, by working through the thinner *parietes*, has tended to improve this communication: for we find in the laterite cliffs of Beder, where a horizontal layer of impervious matter occurs in the substance of the rock, that the sinuous tubes in the laterite immediately above it, have been diverted from their usual obliquely downward direction, to one nearly horizontal, showing that the water, on arriving at this obstruction to its progress downwards, spread itself laterally and horizontally over its surface.

In the same cliffs empty sinuous tubes, having a generally vertical direction, are observed, varying from a few lines to two inches in diameter, and passing from the surface of the rock to considerable depths in its substance. One was traced thirty feet until it disappeared in a projecting portion of the cliff.

They occur on a still greater scale, forming caverns of great extent, if we believe one tenth part of the native traditions regarding them. Such is the cave shrine of Sheikh Furreed at Cuddry, about two miles from Mangalore[1]. This is a hole in the centre of the side of a perpendicular rock composed of laterite, which is said to lead all the way to Hydrabad, 450 miles! The opening is square, about six feet above the ground, ascended by a flight of stone steps, just large enough to allow a person to crawl in. The cavern is very dark, and no one knows the exact size of it. Adjoining is a chasm in the rock, and of inconsiderable size, which at its entrance has been built up with stone, and an opening left for people to creep in by, as in the other; but this is found open within (or exposed to the air) after it is once entered. More than a century ago, a Mahomedan recluse, named Sheikh Furreed, took up his abode in the cave, and at the expiration of twelve years disappeared, and has never been heard of since. The popular tradition is, that he tried to get to Mecca by this subterraneous route!

There is another cavern of considerable size, in the laterite cliffs cresting the Sondur Hills, on the table land of the Ceded Districts, into which I penetrated a considerable distance; but not being provided with torches was compelled to return. The entrance was of an irregular oval form, not exceeding six feet in height, and bifurcating a few paces from the entrance into two winding galleries, leading obliquely downwards into the bowels of the rock. The floor is broken by rugged step-like descents. The cavern drips with water, and swarms with bats, hosts of which were disturbed by my intrusion. Its floor is formed of lateritic detritus, covered with the filth of bats,

[1] Dr. Herklot's Qanoon-i-Islam. Glossary, pp. LXIX and LXX.

into which I dug for several feet in the hope of finding fossil bones, but was disappointed. The natives aver the cavern was the abode of a giant of old, and that it is of incredible extent.

There is a similar cavern in the laterite hills of Ingleswara, in the Southern Mahratta country, (of the extent of which the natives have the same extravagant traditions,) and said to communicate with another cavern at Nagarhal. In the laterite cliffs of Beder, a narrow winding cavern, about sixty yards in length, forms the outlet of the fine spring of the Farabagh. The Brahmans, ever vigilant in turning the phenomena of nature to extending their dominion over the minds of the superstitious Hindú, have seized on both these last caverns, have converted them to places of idol worship, and guard their entrances with Cerberean pertinacity.

In the lateritic belt running west of Indore, Oojein, Mahidpore, and Barode, I perceive Captain Dangerfield[1] has marked down in his map the site of some caves at Doomnar.

The water that percolates through the roof of these caves in the laterite is often charged with iron, which it deposits in stalactitic, or botryoidal incrustations. The same occurs on a much more minute scale in the smaller tubular and vesicular cavities. Curious spheroidal, reniform, and cylindrical bodies, often as large as a cocoa-nut, have been found in the laterite and mistaken for fossil seeds. Their *parietes* are usually composed of gritty particles of quartz, often stained by iron, cemented by a ferruginous matter: their cavities, often empty, usually contain an ochreous, siliceous, and argillaceous dust; as at Stripermatoor, and Pondicherry.

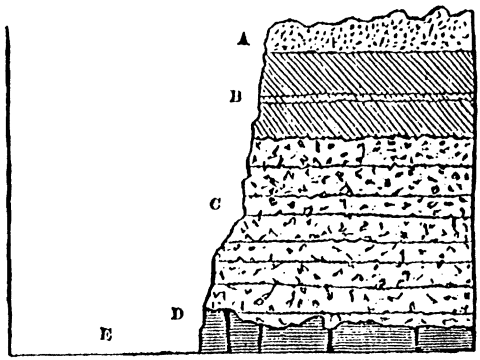
Associated Minerals.—Nodular, reniform, and pisiform clay iron ores occur pretty generally distributed. I have discovered veins and nests of black manganese in the laterites of Beder, Calliany, Ingliswara, &c., also alum, and muriate of soda, in that of the Ceded Districts near Bellary; large beds and nests of lithomargic earths, and white porcelain earths, are not uncommon. General Cullen informs me he found a layer of lignite in the laterite of the western coast at Korkully, about fifteen miles south of Quilon, imbedded in a stratum of dark shales and clays. The bed was quite insulated, slightly inclined, and of a lenticular form, five or six feet thick at the most: the upper portion of the cliff, which is about eighty feet high, consists of the indurated dark red laterite, gradually changing, as the depth increases from the surface, into bright and various colours: in these lower portions the bed of lignite occurs.

[1] Malcolm's Central India, Vol. II., Geolog. Map.

General Cullen recently writes me that lignite occurs in other localities in the laterite of Travancore, and that graphite in scales seems to be rather common in it; chiefly conspicuous in the laterite about Trivandrum and Quilon. It occurs still further south in large and thick scales, and disseminated very generally also in a kind of laterite close to the foot of the mountain, about twenty-five miles east of Trivandrum.

In 1840, I discovered a bed of lignite with resinasphalt, sulphur, alum, (the result of decomposing iron pyrites,) and mineral copal, near Beypoor in the vicinity of Calicut on the Malabar coast, in a bed of loose sandstone, into which the laterite passes, on the right bank of the river, immediately imbedded in layers of black carbonaceous and aluminous shales and clays containing scattered spangles of mica.

The following is a section of the beds, which rise about forty feet above the river's then level.



A Sandy alluvial soil.

B Loose lateritic sandstone with beds of ochreous earth.

C Gritty sandstone passing into laterite; variegated in its lower portions with red and yellow bands.

D Stratum of black aluminous shale and clay imbedding the lignite, &c.

E Level of the river.

The beds dip conformably at an angle of four degrees towards the north-east. The lignite bed can be traced about half a mile easterly up the river where it dips below the river's level. Its structure is obscurely stratified, crossed by vertical fissures, surfaces of which are frequently covered with a yellowish efflorescence, consisting of sulphur, iron, and alumina; sulphur, and oxide of iron, also occur uncombined. The carbonized branches, leaves, and trunks lay horizontally in the black shale. Some were fibrous, toughish when struck by the hammer, and heavy, resembling wood recently charred: others were

brittle with a resinous fracture and lustre, resembling bitumen. Many fragments were penetrated with water, holding iron and alum in solution: the former of which appeared on their surface as a glittering reddish-brown coating. The woody structure was, in general, sufficiently distinct to show that the principal trees imbedded were dicotyledonous. Impressions of leaves and stems of plants were abundant between the layers of shale; but I did not observe any of the dicotyledonous seeds which occur in the lignite beds of Travancore. Some were perfectly black; others of different shades of brown exhibiting different degrees of carbonization. A portion of a black carbonized leaf burnt slowly with a slight flame into a reddish ash, white on the edges. This being subjected to the reducing flame melted on its edges partly into a greenish enamel, and partly into a dark slag affected by the magnet.

The imbedding black shale decrepitated slightly before whiteness, emitting an odour like that of burning coal. It finally fused on the edges into a light greenish-grey enamel, slightly magnetic. The most resinous portions of the carbonized wood burned with a clear flame and bituminous odour, into a white ash: while those in which the elasticity of the woody fibre was less impaired, scarcely gave out any flame at all, burning into a reddish-brown cinder. The odour emitted, however, resembled that of coal more than that of burning charcoal. The cinder fused before the blow-pipe, after giving out two or three bubbles of gas, into a black slag readily attracted by the magnet. The yellowish cauliflower-like efflorescence on the surface of the carbonaceous bed emitted distinct fumes of sulphur on being subjected to the oxidizing flame; melting, after considerable gaseous extrication, into a dark cinnabar-red globule, which, on being subjected to the reducing flame, was converted, with diminution of bulk, into a black magnetic slag.

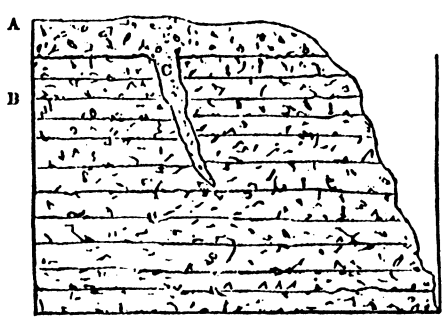
The change of colour and driving off the carbonaceous matter by heat, tended greatly to develope vegetable character, fibre, &c., where none was before apparent, or very obscurely so. The specific gravity of the heavier portions is 1·270, slightly exceeding the average specific gravity of coal, which is 1·250. This deposit of vegetable matter has evidently been made tranquilly, from the flat horizontal position of the layers of leaves and stems.

Since writing the above, General Cullen informs me that he now sees much of the carbonaceous deposit in Travancore, and that it is very extensive. It exhibits itself in beds of black clay and lignite, of from fifty to sixty feet thick, in some places 200 feet, along the laterite cliffs at Venkully, for a distance of three miles; in fact, all

along the coast from Quilon to Venkully. Deposits of the same kind occur about the same level, at the distance of two or three miles inland. A similar deposit is seen on the sea shore, about thirty miles south of Trivandrum. The trunks, or rather their fragments, were both of monocotyledonous and dicotyledonous wood in a state of perfect carbonization, and abounded with sulphuret of iron.

Origin.—Writers on Indian geology are divided in opinion as to the origin of laterite. With regard to the igneous theory as originated by Voysey, taken up by Calder, and put forth by Mr. Conybeare, it must be remarked that, hitherto, no decided volcanic product has been discovered in laterite, no crater or other proof of such origin. It is true, it is frequently seen overlying trap rocks; but it also overlies granite, hypogene strata, sandstone, and limestone, and in none is it ever seen as a dyke; nor are there any signs of forcible intrusion or alteration. In one hand specimen that fell under my observation, the laterite *appeared* to have intruded into and shattered the sandstone; but in every instance where I have had an opportunity of seeing veins, if they may be so termed, of the laterite in other rocks, *in sitû*, they have occurred as deposits *from above*, into pre-existing chinks of the subjacent rocks, like the conglomerate which fills fissures in the limestone of Petit Tor; and never injected from below, as is the case with volcanic rocks.

The following section exhibits the laterite filling a chink in the subjacent sandstone of Ganjicotta, in the Cuddapah district.



A Laterite capping sandstone.
B Sandstone.
C Chink in sandstone filled by laterite from above.

Fragments of trappean, and other rocks, occasionally are imbedded in the laterite; as also in the subjacent sandstone, and in other rocks confessedly of aqueous origin. Cases occur where basalt underlying the trap as at Beder, has the appearance of passing into it: but this,

on minute examination, turns out to be a confused blending of the debris of both rocks near their junction; from which distinct and unmixed fragments of either sort could be separated, like bits of granite from the breccias that are usually found near the junction of the latter with sandstone. In many localities, however, the line of demarcation between the laterite and overlying trap is clear and decided.

Some geologists suppose that laterite is nothing more than granitic, hypogene, and trappean rocks weathered *in situ*. The facts of its imbedding erratic fragments of sandstone, at the Red Hills near Madras, where it rests on granite, and its interstratified beds of lignite and silicified wood, militate strongly against this theory. Besides, nothing is more common in lateritic tracts than to see a hill of granite, trap, or hypogene rock, capped with a thick crust of laterite; while the adjacent hills, composed of an exactly similar rock, and forming a continuation of the same bed, equally exposed to the action of the weather, are quite bare of laterite. I have examined many beds of it resting on trap, and amygdaloid imbedding calcedonies, heliotrope, and jasper, but have not hitherto detected in the upper or middle beds of the former, any fragments of these hard siliceous minerals, which are found to resist successfully the attrition of the most rapid streams of India, and have been carried by them across the peninsula to the ocean.

I have seen laterite, too, resting on limestone, without any traceable lime in its composition: and containing veins of manganese, when resting on a trap in which hitherto the existence of this mineral has not been detected: facts, proving that the overlying laterite was not the upper portions of these rocks weathered *in situ*.

I have often observed, particularly in the Western Ghauts, and on the Malabar and Concan coasts, where the rains fall heaviest, those granitic, hypogene, and trappean rocks, which contain most iron, weather into ferruginous and coloured clays, that sometimes lithologically speaking, resemble laterite; and, when that rock is near, have *the appearance* of passing into it. I have also observed large beds in gneiss and hornblende schist, of an impure oxide of iron, assume a cellular and pisiform aspect; but such must not be mistaken for the true laterite, nor yet the beds of re-aggregated gravel derived from the laterite.

When we look up from the microscopic view afforded by these slowly weathering blocks of rock and beds of ore, and cast our eyes upon even the present extent of laterite over the surface of India, the thickness of its beds, its flat-topped ranges of hills, and the gaps effected in their continuity, evidently by aqueous causes no longer in

action, its occasionally imbedding waterworn pebbles of distant rocks, its often elevated position above the present drainage level of the country, its beds of lignite and silicified wood, we find no more reason for attributing its origin to the weathering of rocks *in situ*, or to their detritus transported by causes now in action, than for attributing the formation of the older sandstones to the present disintegration of the granitic and hypogene rocks, of the detritus of which they were doubtless, as well as the laterite, formed originally.

The supposed non-fossiliferous character of this rock, which has puzzled many geologists, and inclined others to the theory of its ancient or volcanic origin, may in some measure be attributed to its highly ferriferous nature, often approaching that of an oxide of iron. It is a general fact, and, as Lyell observes, one not yet accounted for, that scarcely any fossil remains are preserved in stratified rocks in which the oxide of iron (derived from the disintegration of hornblende or mica) abounds: and when we find fossils in the new or old red sandstones of England, it is in the grey, and usually calcareous beds that they occur. It is well known, too, that some of the more recent tertiary deposits of Europe are entirely divested of fossils.

As this singular variety of ferruginous clay and sandstone has not been mentioned by geological writers on other countries than those I have alluded to, it may be presumed that laterite either does not exist under this form at all, or in such small patches as not to have attracted remark. The question naturally suggests itself, why this cellular rock should be confined to India, &c. The solution may be in the highly ferriferous nature of the plutonic, trappean, and hypogene rocks, from which the laterite has confessedly been derived, and in the supposition of a segregation and subsequent re-arrangement of the different mineral particles in the substance of the rock itself, by a process in nature's laboratory, approaching to crystallization, better known than explained or understood. If electricity, which is probable, has any share in exciting this movement and attraction in the mineral particles of the rock, its metallic nature affords a favourable condition for the active development of this powerful agent. The structure of the rock has received some modification from the action of water, in emptying its cells and carrying their contents to the lower parts of the beds.

Age.—Having said thus much to warrant the classification of laterite among rocks of an aqueous and mechanical origin, I shall proceed to remark that in age, relatively to other rocks of Southern India, it is older than the *regur* and *kunkur*, which it underlies, and of more recent origin than the overlying trap, the shell limestone of Pondicherry, and the diamond sandstone and limestone, on all of which it is

superimposed. It has never been invaded by the dykes of trap that penetrate the latter rocks—the hypogene and plutonic rocks,—fragments of all which it sometimes imbeds, but is evidently contemporaneous with the efforts, or series of efforts, by which the Western Ghauts were lifted above the waters; since it is seen capping their summits, often shattered into large irregular blocks, and stretching more continuously, and with less signs of disturbance, from their base to the sea.

From the non-altered state of the laterite at its junction with the granite, and the imbedded fragments of the latter rock, as well as of fragments of the trap dykes, it may be inferred that both granite and the associated trap dykes were elevated in a solid state. I have classed the laterite as more recent than the Nirmul fresh-water cherts and limestones, on account of the latter rocks having been invaded and altered by trappean intrusion.

Pondicherry Silicified Wood Deposit.

A short distance inland from Pondicherry beds of a loose ferruginous grit rise into a low range of hills, called, from the colour of the rock, the Red Hills. They run in a north-north-east direction, almost parallel with that of the coast. They are about two miles in breadth, and about eight or nine in length. The deposit, probably, extends further in a southerly direction than the north bank of the Ariancoopang river, to which I traced it from the vicinity of Camlaput on the north. The locality where the silicified wood is found in greatest abundance is in the vicinity of Trivicary, about fifteen miles west of Pondicherry. Between the Red Hills and the sea extends a plain covered with an alluvial sandy soil, and underlying it a greyish-black or dark clayey loam, resembling that of Madras, imbedding fragments of grit and recent pelagic shells. The descent from the hills towards Pondicherry is gentle, but steeper on the western flank, where the strata have been evidently stripped off, and the subjacent fossiliferous limestone denuded[1], leaving a shallow valley, marking the discontinuity of the strata, between this point and where the beds again appear in the vicinity of Trivicary, on the opposite or western side of the valley.

Here they form a low broken range of hills, not rising higher than from fifty to one hundred feet above the general level of the plain, having a parallel direction with the beds on the eastern side, and sloping gently towards the east. The western flank is rugged and preci-

[1] Vide Section accompanying description of the shell limestone of Pondicherry, p. 214.

pitous wherever it meets the hornblende schist, which flanks it to the west, near the village of Trivicary. A narrow valley marks the junction line, covered with the detritus of both rocks. Here silicified trunks of trees have been imbedded in the grit in a nearly horizontal position. The stems are both strait and crooked, generally without roots or branches; though the former have been found, and the places of the insertion of the latter are frequently strongly marked on the stem. They are monocotyledonous, and dicotyledonous; coniferous, and non-coniferous. Dicotyledonous wood is, however, most abundant. One of the trunks I found to measure twenty feet in length, and from one to two and a quarter feet in diameter.

Lieutenant Warren, in the Asiatic Researches, describes a trunk about sixty feet long, and from two to eight feet in diameter: but this has been broken up by the native collectors of petrifactions. The organic and microscopic structure of the wood, in many specimens, is beautifully preserved. The siliceous matter of petrifaction is often semi-transparent, like chert, or calcedony, or opalized, or striped with lively bands of red, like jasper. It varies in colour and texture from an opaque whitish chalk-like stone, to a red and white carnelian, giving fire with steel; the prevailing tints are delicate shades of brown and grey. The inner portions of the tree have been usually more perfectly fossilized than the exterior; which appears to have been, in many specimens, bruised as if by drifting, and deprived of its bark. The outer portions usually exhibit the most lively colours. Drusy crystals of quartz sometimes line their cavities. The carbonaceous matter of the wood has entirely disappeared, and nothing but silica and iron left.

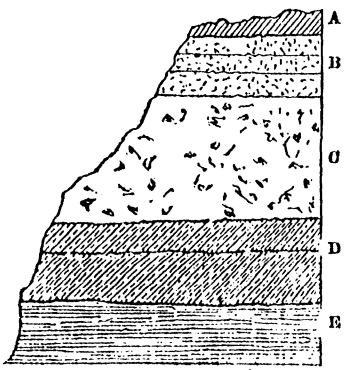
The fossil trunks and fragments of silicified wood occur partly imbedded in the rock, and partly scattered over the soil and detritus. Numbers have been broken and destroyed by the natives to sell to the stone polishers, who manufacture the most attractive fragments, under the name of petrified tamarind wood, into brooches, seals, beads, studs, bracelets, boxes, &c.

Although fragments of silicified wood are found scattered here and there over the whole extent of this lateritic grit, yet the space into which the largest fossil trunks at Trivicary are crowded does not occupy an area of two square miles. There are no signs of any bed, like the Portland dirt-bed, in which they formerly grew, and no carbonaceous matter; and I have little doubt the trunks were drifted to the situation where they are now found at the edge of a granitic shore, and covered with sand and pebbles: it is very clear that they did not grow on the spot where they are now found petrified, mutilated, and prostrate, as supposed by many travellers.

Lithologic character of the Rock.—The imbedding rock is for the most part composed of angular grains of quartz, often stained with iron, and loosely cemented together by dark red and whitish clays, passing into a conglomerate, and into a tubular and cellular rock, differing in no respect from some varieties of laterite. The latter is seen at intervals occupying an exactly equivalent position along the coast to the northward. It imbeds similar layers, and nests of lithomargic earth. The singular hollow spheroids and tubular bodies, already described, are common to it and to the beds to the north in the vicinity of Madras. They have been mistaken for petrified fruit and seeds, but possess no traces of organic structure; and, in many cases, have originated from the action of water on the porous structure of the rock. The imbedded pebbles are both rounded and angular, the former predominating,—and are for the most part of quartz and chert, with a few pebbles of trap and the hypogene rocks.

The beds near Trivicary are shattered by deep vertical fissures. Their surface presents strong traces of watery erosion in a number of channel-shaped, sinuous, and basin-like cavities, some in situations above the influence of present drainage. Many of them contain sand and water-worn pebbles, similar to those in the subjacent rocks. Among the gravel scattered on the surface I found a pebble of the subjacent limestone, and several of greenstone.

The following presents a section afforded by some cliffs near the south-west extremity of the Red Hills.



A Surface gravel, about 2 feet thick.

B Loose red grit, about 4 feet.

C Grit with fragments of weathered quartz and felspar, 8 feet.

D Red grit with rounded pebbles of greenstone and quartz, passing in its lower portions into a variegated red and yellow grit, 5 feet.

E Variegated red and yellow grit, 4 feet.

All the beds below the gravel are interstratified with thin layers of purplish and white lithomargic clays, resembling those in the laterite.

The silicified wood of the Egyptian desert closely resembles that of Pondicherry, as also the rock in which it is imbedded at the "Fossil forest," near Cairo, not only petrologically, but in *gisement*. Both occupy overlying situations covered with gravel, sand, and other detritus, and rest on a marine limestone in strata but little inclined from the horizontal. Both have suffered from aqueous denudation exposing the subjacent limestones. I could not discover the least trace of extinct volcanos, or of volcanic substances, in the vicinity of either.

I am not aware of any other places in Southern India where fossil wood is found except Mungapett[1], and a few other localities on the banks of the Godavery and Wurda, where silicified coniferous wood occurs in very small quantities, and at Hingan-ghaut, on the north bank of the river, where silicified branches of dicotyledonous trees, and a very perfect portion of a palm,[1] were found in loose blocks of a black and red chert resting on the newer trap formation: I am rather inclined to refer this to the fresh-water chariferous limestone and chert formation, than to the laterite and Pondicherry beds.

Marine Sandstone Beds of Ramnad and Cape Comorin.

On the eastern coast, near the southern extremity of the peninsula, are some beds of sandstone. The shells they imbed (as far as their fractured state would admit of their being recognised,) are of species existing in the adjacent sea; they are tertiary, and may be classed, for the present, with the laterite and Pondicherry sandstone. The rock is of a less ferruginous character than either, and consists of a marine sand, rather loosely aggregated.

It occurs in some cliffs on the coast of Ramnad and stretches across the straits to Ceylon, as a low interrupted ridge, partially covered at high-water mark, and known by the name of Adam's Bridge.

Some of the more solid portions of this ridge, or reef, still remain in an insulated position, considerably elevated above the water's edge: for instance, the two hills on the island of Ramisseram, and the island of Manar. The intervening portions, and the direction of the ridge, are marked by a chain of sand banks; based, there is reason to believe, on the same sandstone which is found below the water level in the Paumbam passage.

This singular barrier of rocks, through which Government has succeeded in blasting a narrow passage, and partially opening the navi-

[1] Malcolmson, Madras Journal of Literature and Science, July 1836, p. 216.

gation of the Manar Straits to steamers and other vessels of small draught, formed once the bed of the sea; and was subsequently elevated to its present position, probably at the same period with the laterite.

The strata are perfectly horizontal, and rest on a bed of gravel in some places consolidated into a conglomerate[1]. Similar strata form the geological structure of the southern portion of Ramnad and Tinnivelly.

Near Cape Comorin similar beds of marine sandstone are said to occur. Dr. Davy[2] notices identical beds of sandstone on the opposite coast of Ceylon, which he describes as being composed of siliceous sand, and minute fragments of shells: he considers it recent, and the process of consolidation still going on. It has, he observes, formed in many places below high-water mark.

Captain Jenkins, of the Quarter-Master-General's department, informs me that the natives have a tradition, that the low country of Ramnad, as far as Madura, was once covered by the sea.

PART VII.

Older Alluvium; Changes in Level of the Land and Rock Basins.

The rarity of beds and scattered boulders of true drift in Southern India, may be considered to add to the evidence already accumulated in favour of the theory, that icebergs floating in the ocean have been mainly instrumental in the transport of the vast masses of rock and detritus, principally granitic, which cover tracts of land in the higher latitudes of Europe and North America; indicated chiefly by their prevalence in northern regions, and rarity in those bordering, and within the tropics, and their recurrence in high southern latitudes; for instance, in Chili and Patagonia, where they appear with precisely the same unstratified aspect, the same mixture of vast rolled and angular blocks transported to great distances, over chains of hills, rivers, &c., from their original *situs*.

It is well known that the usual course taken by icebergs from the confines of the polar circles of eternal congelation is towards the tem-

[1] Madras Almanac, 1841, p. 47; Account of Ramisseram, by Assist.-Surgeon J. Kellie.

[2] Trans. Geol. Soc., Vol. V., Part II., p. 326.

perate latitudes. These icebergs, as we know from the writings of Scoresby[1] and other navigators, have been seen drifting from the arctic regions freighted with beds of rock and earth, the weight of which was conjectured to be from 50,000 to 100,000 tons. These icy vehicles, long before arriving at equatorial regions, melt and shower down their rocky burthen on the bed of the ocean, or, stranding on some coast, gradually dissolve and deposit the blocks and sand in one confused heap.

Brogniart, apparently on the authority of M. de Luc, has given his opinion, that the blocks of granite around Hydrabad are real boulders; but after a careful examination, I feel convinced that these masses are *in sitû*, and resting on a granite and its detritus perfectly identical with that of which they are composed. They owe their globular shape, their scattered and isolated position, to such a process of weathering and spontaneous concentric exfoliation as I have attempted to describe in a previous and separate paper, on the subject of the Granites of India and Egypt.

As the terms "drift," "boulder formation," and "diluvium," have been latterly almost exclusively applied to the detritus supposed to have been deposited by the thawing of glaciers or icebergs, I have thought it requisite, to avoid any mistake as to their origin, to apply the designation of alluvium, in its extended sense, to certain beds of gravel and sand that are occasionally found covered by the regur deposit, and which occur in such situations as not to be accountable for by the agency of existing transporting powers; simply prefixing the term "older" to distinguish it from the alluvium now forming from the disintegration of rocks washed down by the rains and springs, and transported by rivers and local inundations.

The beds of older alluvium have been little attended to by Indian geologists; and few have therefore been described. Future investigation, I have little doubt, will disclose to us many more deposits than those now about to be pointed out.

Diamond Gravel of Cuddapah.

At Condapetta, in the Cuddapah diamond district, underlying a bed of regur in some places twenty feet thick, is found a gravel bed, which I found to cover an area of several miles, from two to six feet thick, resting upon the diamond limestone. I saw no pebbles, (with the exception of a few nodules of *kunker* which may have been recently formed in it,) of more recent origin than the diamond sandstone

[1] Voyage, 1822, p. 233.

and limestone. It was principally composed of rounded fragments of trap, granite, and the hypogene schists, which must have been transported from the distance of twenty or forty miles, intermingled with pebbles of quartz, jasper, and chert, and others from the adjacent sandstone and limestone. In this gravel, intermixed with kunker and iron ore (the oxide), the diamond is found as a transported crystal or pebble, often fractured, and with slightly worn edges. The diamond gravel near Parteal[1] consists of a bed two feet thick, composed of pebbles of sandstone, hornstone, quartz, jasper, and flint, with fragments of occasional rocks, epidote, and abundant ferruginous sand, lying under a layer of tufaceous carbonate of lime (kunker) cementing similar gravel, but in which the diamond never occurs. Both deposits are covered to the depth of fifteen feet by the recent alluvium of Ellora, which overspreads the space between the deltas of the Kistna and the Godavery.

Wakoory Bone Deposit.—In the Nizam's territories[2], at Wakoory, about twenty-two miles south-east from the cantonment of Hingoli, is a bed of gravel, cemented by kunker, which appears to underlie the whole valley of the Baingunga; and there is reason to suppose that the same stratum underlies the alluvial black soil of the valleys in the vicinity of Hingoli. In 1837 the river at Wakoory rose to an unprecedented height; the stream left its own bed; and, in falling into the Baingunga river, about a mile from Wakoory, washed away much of the black soil from the right bank, thus exposing the substratum of gravel cemented by kunker. A considerable portion of the latter was also cut away, by the force of the water in its fall of about forty feet into the Baingunga.

During the process, the tusks and bones of a large animal were washed bare, at a depth of from forty to fifty feet, imbedded in the gravel. The village cow-herds, it is said, broke the bones, and otherwise destroyed the skeleton, before it was known at Hingoli that such discovery had taken place. Steps, however, were taken to prevent further destruction, and all that appeared were secured; viz., three pieces of the tusks (there were two tusks distinct, *in situ*, in the gravel forty feet below the surface,) and one long fragment of bone; all the other large bones had disappeared. A mass about five feet long and two feet broad of jumbled bones and gravel, remained.

Part of the tusk, half fossilized by carbonate of lime, I took to England in 1841, and showed it to Professor Owen, who immediately pronounced it to be fossil ivory; probably a Mastodon's tusk.

[1] Captain Macpherson, Asiatic Researches, Vol. XVIII., pp. 118 and 119.
[2] Madras Journal of Literature and Science, for April, 1838, p. 477.

The large collections of fossil bones from the basin of the Jumna[1], were found under the kunker clays of the Dooab, 150 feet below the surface, but the sand and gravel of the Sewalik and Nerbudda bone beds were cemented, like the gravel bed of Wakoory, by calcareous infiltration.

During the boring experiment at Calcutta in 1837, a fossil bone, —the fractured lower half of a humerus of some small animal of the canine species,—was brought up by the auger from a depth of 350 feet below the surface of Calcutta, in a bed of quartzose and micaceous sand, about 250 feet below the extensive alluvial deposits of the yellow kunkery clay, which entirely cover, or rather form, the Gangetic Plain. The sand bed was underlain by a bed of black peat clay, imbedding black carbonized wood, between peat and lignite, and perfectly carbonized wood, resembling the Assam coal, in rolled lumps. The last were found at the depth of 392 feet. Two fragments of fossil Testudo, and a rolled fragment of vesicular basalt, were brought up from the great depth of 450 feet.

Western Coast Deposits.—Professor Orlebar informs me that underlying the regur, at Baroche, on the western coast, are beds of a yellowish-brown micaceous sand imbedding nodules of kunker, extending so far inland as Ahmednugger and Deera. They rest on trap, granite, and a sandstone resembling that of Badami. No organic exuviæ were found in these deposits.

Deposits in the Valleys of the Bima, Kistna, Tumbuddra, &c.—In the valleys of the Bima, the Kistna, and the Tumbuddra, and other large rivers, are occasionally seen beds of alluvial gravel elevated beyond the highest existing inundation lines. Some of these deposits may be ascribable to shifts from time to time in the course of the river's bed; a few to the action of rain in bringing down alluvium from the mountain sides; but the majority appears to have been accumulated under conditions not now in existence; probably, during the slow upheaval of the Western Ghauts and plateau of the Deccan, when the water occupied a much greater extent than at present. In many places the rivers have cut their way through these deposits; in others, channels exist of rivers, where now, as in the *Bahr bila maieh*, in Egypt, no water flows, or but a diminutive streamlet.

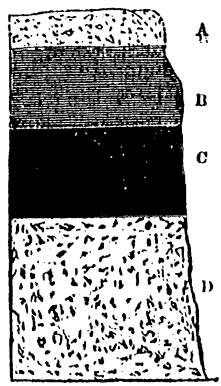
Captain Allardyce, a most intelligent and accurate observer, informs me that the Moyar valley, which runs along the table land of Mysore by the base of the Nilgherries, differs entirely from a common mountain glen. Though a mile or more in breadth at some points, yet, it is rather a ravine, or fosse, cut in the plain and not hemmed in

[1] Madras Journal of Literature and Science, for April, 1838, pp. 475 and 476.

by mountains. It opens out into the lower plain of the Carnatic, at the Gujulhutty Pass: the sides are precipitous, and its bed very much like the deserted channel of a river. The only stream now flowing in it is the Moyar; which, even in the monsoon, does not fill one hundredth part of its breadth and heighth: yet, this singular excavation, extending some thirty miles in length, is unquestionably a waterworn channel. It is no fissure; for its bed is quite solid and connected, and composed of strata of the hypogene rocks.

Gravel on summit of Nilgherries.—On the summit of the Nilgherries, at an elevation of above 6000 feet from the sea's level, Captain Allardyce informs me that he observed traces of a diluvial current. He states that the gravel and loam there are arranged in such a manner as could only take place by deposit from water; the gravel being lowest, in a thin, distinct, and separate stratum, with the lighter loam covering it to the thickness of several feet. Benza mentions[1] having picked up at the base of these mountains, near Motipollium, a fragment of black mountain limestone, a rock which is not to be found *in situ* within hundreds of miles. The brooks, even on the summits of the Koondahs, are seen threading their way through beds of alluvium which they could not have deposited under existing conditions.

Nellore, Pondicherry, and Madras Marine Alluvium.—Pondicherry stands upon an alluvium resting on beds of dark blue, or grey marine clay, which extend inland nearly to the base of the Red Hills. The following is a section afforded by a recently sunk well in the town.



A Is a layer of a reddish brown sandy soil two feet thick.

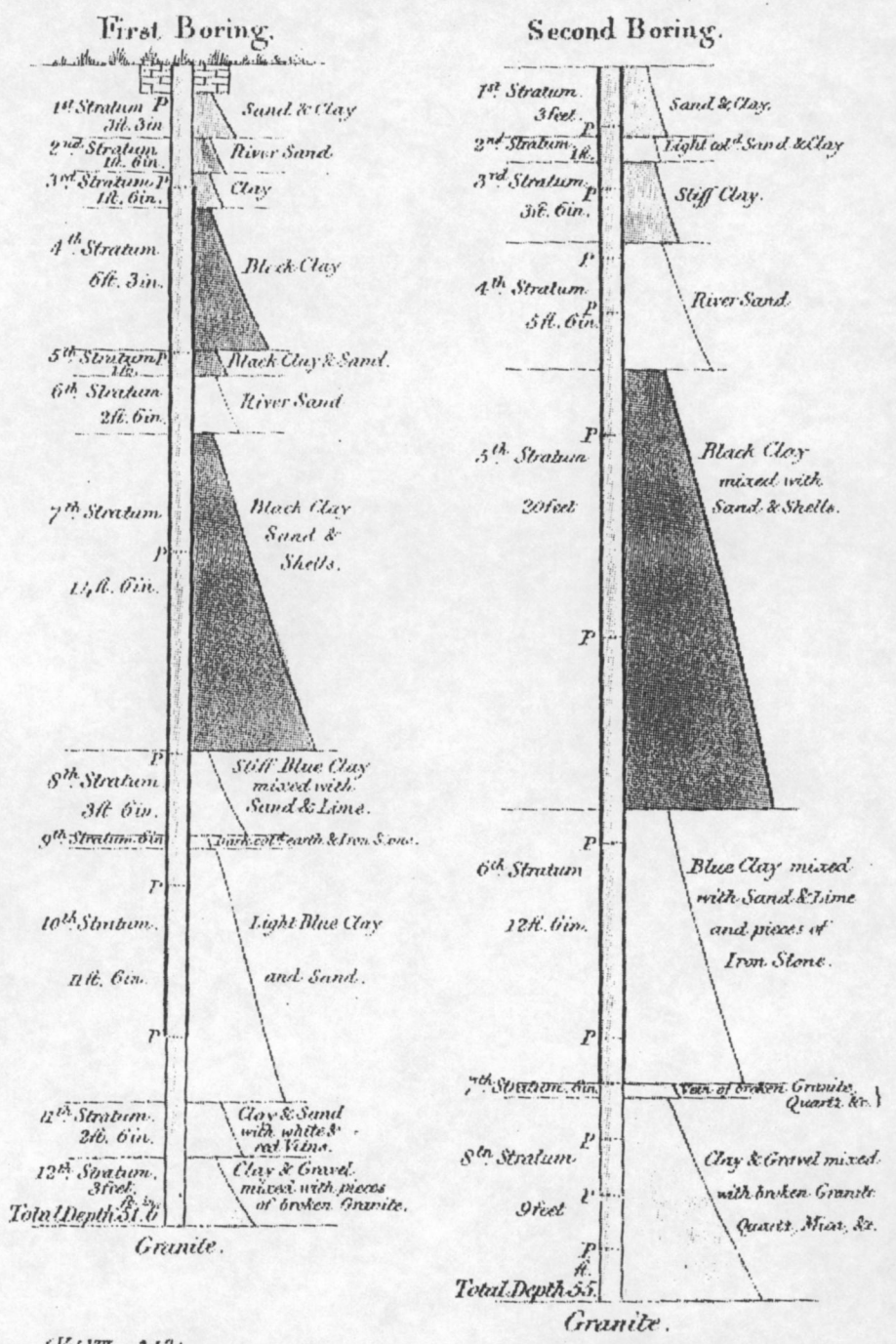
B A bed five feet thick of a blackish clay mingled with a small quantity of grit, and containing existing marine shells.

C Bed of black clay almost pure, also five feet thick.

D Beds of reddish quartzose sand, about ten feet thick.

[1] Madras Journal of Literature and Science, Vol. IV., p. 27.

Sections of Two Experimental Borings of the Earth at the Land Custom House, Madras. Executed by Order of Government in Oct.r & Nov.r 1832.



(Vol. VIII. p. 249.)

Near Cottapuram and Kistnapuram south of Nellore I found similar beds of marine clay underlying the alluvial sand. The water percolates through the loose texture of the arenaceous stratum and collects in hollows in this impervious clay bed below, forming the reservoirs down to which the generality of the wells are sunk. As might be expected, the water is, in general, slightly brackish.

I have observed in other localities on the Coromandel coast beds of this dark clay, at depths of from twelve to twenty feet below the present sands and alluvium, imbedding existing marine shells, and extending inland, sometimes two or three miles. On the alluvium covering them, stand Hindu villages, pagodas, and ruins of high antiquity. Over one of these marine beds the greater part of the European portion of the city of Madras is situated, separated by a bed of sand, clay, and soil, from five to fifteen feet thick. South of Madras, beyond the Adyar river, this dark-coloured clay abounds so much in large and thick beds of marine shells, that it is covered with excavations made by the chunam-getters of Madras, who use the shells to burn into that beautiful marble-like lime, so great an ornament to the churches and other buildings at Madras. These shells are preferred to those at present thrown on the sea beach, as freer from saline impregnation which makes the chunam liable to crack in drying.

The saline matter has evidently been carried off for the most part by the fresh-water springs or rivulets of the marshy grounds under which the deposit lies, and which was probably a small estuary or inland lake; the surface, even now, is so low as to be mostly under water during the monsoon. Small rolled fragments of carbonized wood between peat and lignite, occur in it.

The lithographed drawing exhibits two sections of the beds on which the city of Madras stands, down to the granite which is found in the deepest, No. 2, at the depth of fifty-five feet,—afforded by borings near the land Custom-house, about three-quarters of a mile inland from the sea. Intervening between the black clay and the granite, will be found first a bed of blue clay mingled with sand, lime, and pieces of "ironstone" (laterite?); and resting immediately on the granite, a bed of clay and gravel mixed with broken granite, quartz, &c. It does not seem at all improbable that the dark clay is identical with the regur. No organic remains, except marine shells, have hitherto been discovered in it.

These marine deposits were elevated evidently during the Post-Pliocene period, by forces which it would appear are not at rest; and, perhaps, like those affecting some tracts along the shores of the Baltic,

cause an undulating movement, raising some parts, and depressing others, while some rest stationary.

Of the elevatory movement on the Coromandel coast there can be little doubt, from the decisive evidence of the raised inland marine beds; and it is stated that Masulipatam, once close to the sea, is now nearly a mile inland. The Puranas assert that the whole of this coast has been raised from the bed of the sea. With regard to the last fact, and to the sinking of the coast in certain places, it must be borne in mind that alterations in the configuration of a coast, caused by storms, unusually strong swells, and partial elevations of the sea's bed, will affect other portions of the same coast to which the current may be deflected.

We have now arrived at the traditional and historical period, and I shall proceed to state a few of the cases where what was formerly said to be land is now covered by the ocean.

Mahabalipur.—It is stated in Brahmanical writings that the ancient city of Mahabalipur, (now termed the Seven Pagodas,) about forty miles south of Madras, was anciently overwhelmed by the sea, which now rolls over the greater portion of the submerged ruins. It is supposed by some to have been the Palibothra of Ptolemy, a place of considerable commerce. I was informed by Lord Elphinstone and Mr. W. Elliot, that whenever a storm took place from the seaward, Roman, and occasionally Chinese coins were cast upon the beach. One of the former, according to Mr. Norton, is of the reign of Valentinianus. General Fraser informs me that south of these ruins, at Ariacoopang and Cuddalore, pieces of brick, tiles, and pottery are taken up from the bed of the sea at considerable distances from shore, beyond the recoil of the tidal wave. Still further south, near the embouchure of the Cauvery, the Brahmans point out the submerged site of another ancient city. At Madras, from all I can collect from the oldest inhabitants and survey, the sea has certainly encroached latterly on the ground it formerly occupied: while St. Thomé, an ancient Portuguese settlement, a little south of Madras, is traditionally said to have stood twelve leagues inland[1].

Adam's Bridge.—The celebrated ridge of rock called Adam's bridge, which the Brahmans (confirmed by the records of the Pagoda at Ramisseram) assert, formerly connected Ceylon with the peninsula of India, and believe to have been miraculously constructed by Rama, is now submerged at high water, having been broken through by a storm in the fifteenth century. The rock of which this ridge is com-

[1] Sousa's Portuguese Asia, Tom. I., p. 270.

posed is of a loose sandstone, imbedding fragments, apparently of existing marine shells, and formed at no distant period part of the bed of the sea. It is connected with beds of a similar rock on the continent, and on Ceylon. The natives believe that the whole of the adjacent low country of Ramnad has risen from the ocean, to the extent of seventy miles inland.

Malabar Coast.—Indications exist of the sea having covered certain parts of the Malabar coast to a considerable distance inland. The present town of Barcoor, north of Mangalore, supposed by Rennell and Robertson to have been the Barace of ancient geographers, and which now stands two or three miles from the sea, is said to have formerly stood on the shore, and its port to have been frequented by large ships from various regions[1]. Some of the cliffs running parallel with the present coast, at some distance inland, have every appearance of having been formerly washed by the sea; and the Brahmans assert, that the whole of the Malabar coast was raised from the ocean for their special use.

Frequent mention of earthquakes[2] may be found in the history of the Malabar coast, which extends from Cannanore to Cochin, about forty-two leagues. In 1784 a strong concussion was felt. "The most remarkable changes are to be found in the vicinity of Cochin. On its north side we find the island Vaypi, which was thrown up by the sea about the the year 1341. The soil upon this new formation resembles that of the flat districts of Malabar, which consists of sea-sand and calcareous matter combined with clay, said to be washed down from the Ghauts.

"The production of this island had so strong an effect on the minds of the Hindus, that they marked the geological phenomenon by commencing from it the new era, termed *Puduvepa* (new introduction). Contemporaneous with the appearance of the island of Vaypi, the waters, which during the rainy season are discharged from the Ghauts, broke through the banks of the river Cochin, and overwhelmed a village of the same name, with such impetuosity as to sweep it away,

[1] We learn from Pliny and Arrian, that Barace was the principal emporium of Indian trade. It was frequented by the ships of the Alexandrine merchants, which sailed from the port of Berenice in the Red Sea, during the south-west monsoon, to Muziris or Mangalore; but in consequence of that place being infested by pirates, they preferred staying at Barace till the beginning of December or January, when they returned to the Red Sea.

[2] Bartolomeo, quoted by Dr. R. Thomson. Madras Journal of Literature and Science for January, 1837, pp. 176, 177.

and formed in that district a river, a lake, and a harbour so spacious, that very large ships can now lie in security on the north-east side of Cochin, where the river runs into the sea."

Submergement of the Old City of Calicut.

In some places, as on the Coromandel coast, tracts formerly inhabited have disappeared under the sea. The bank on which stood the old city of Calicut (the landing-place of Albuquerque,) a little to the south of the present site, is now buried under the sea; but it does not appear at all clear whether in this, or other cases of submergement, the cause was a sinking of the land, or a change in the configuration of the coast by a sudden rise of the sea. It is said that the remains of an old factory are to be seen in the surf off Purkaad and those of Pagodas in the surf at Tricanapully on the coast of Travancore. The subject is one of much interest, and requires patient and careful investigation. What has been stated above is more with the view of eliciting inquiry than affording solid material for a theory. Marks on cliffs washed by the sea, and registers of the height to which it rises, as adopted on the shores of the Baltic, would be of great use.

Shocks of earthquakes are not unfrequent in the maritime districts of Nellore and Guntoor; and I lately felt one very distinctly, attended with a noise resembling the subterranean rumbling of a train of heavy carriages along the gallery of a mine, on the table land of Kurnool. No volcanoes, either in an active or a dormant state, are known to exist in Southern India, though one occurs in the Andaman islands in the Bay of Bengal.

Regur, or Black Cotton Clay.

Geographic Position.—This singular deposit covers, in sheets of considerable thickness, at least one-third of Southern India. It occupies principally the elevated table lands of the Ceded Districts, the Hydrabad, Nagpore, and Southern Mahratta countries; including thereby the whole of the plateau of the Deccan. It is less common in Mysore, but is again seen in continuous sheets from six to twenty feet thick below the Salem track, covering the lower plains of Coimbatore, Madura, Salem, Trichinopoly, Tanjore, Ramnad, and Tinnevelly, to the vicinity of Cape Comorin.

It is rarely seen on the maritime plains of the Carnatic, and I have

never observed it below the escarpment of the Western Ghauts on the coasts of Malabar, Canara, or Travancore.

Physical Aspect.—The plains occupied by the cotton soil are in general marked by their horizontal sea-like surface and almost treeless aspect. The vegetation which almost characterises it is the shrub *Jatrophus glandulifera*, and the *nuth* grass. It is often covered with bushes of the thorny acacias, cassia auriculata, asclepias gigantea, butea frondosa, &c.

Geognostic Position.—It covers the kunker and gravel beds just described, and is generally seen as a surface soil; but if we examine the edges of great sheets they will generally be found to dip for some distance under the recent alluvium, which conceals and replaces them as a surface soil. It not only covers extensive plains, but the tubular summits of hills overlooking those of the diamond sandstone and limestone, newer trap and laterite formations, far above the present drainage level of the country: it covers all rocks from the granite to the laterite and kunker; and often fills up depressions and chinks in their surface, as seen in the accompanying section. Soundings on a bluish-black clay are obtained in various situations off the Coromandel coast, which closely resembles the régur, as also the blue clay imbedding the marine shells below the cities of Madras and Pondicherry. Part of this deposit, it is not improbable to suppose, may have been derived from the denudation of the régur that once covered the maritime tracts of the Coromandel coast.

A A A Recent detritus and alluvial soil.
B B B B Regur.
C Kunker.
D D D Laterite.

Composition, &c.—The purest regur is usually of a deep bluish-black colour, or greenish, or dark greyish black, fracture varying from shining to earthy, streak brownish, or greenish black, shining; when placed in water it crumbles slowly with emission of air bubbles, and forms a tenacious paste; when moistened it gives out an argillaceous odour. Before the blowpipe, *per se*, it melts into a greenish glass, or dark slag. Mr. Reid fused some of it in a large covered crucible placed in a furnace into a solid mass, on the surface of which a crust

of oxide of iron formed. A chemical analysis made by my friend Dr. Macleod afforded the following result.

Silex	48	2
Alumina	20	3
Carbonate of lime	16	0
Carbonate of magnesia	10	2
Oxide of iron	1	0
Water and extractive	4	3
	100	0

The quantity of iron it appears by this analysis is not sufficient to account for the black colour of this soil, which may be partly attributed, as in the case of the Cuddapah limestone, to the extractive or vegetable matter it contains. The regur of Trichinopoly, I am informed by Captain Allardyce, does not fuse, and contains imbedded crystals of pure mineral carbon, which are converted before the blowpipe into a white ash. There is, no doubt, nearly as great a diversity of composition in the regur deposit, as we find in other equally extensive aqueous rocks.

The best kinds of this extraordinary soil are rarely suffered to lie fallow, except by accident, and never receive manure, which is even supposed to lessen its fertility. It has yielded annually, crop after crop for upwards of 2000 years (usually in triennial rotation) of cotton, juari, and wheat, or bajri, without receiving any aid from the hand of man, except an annual scratching with a small plough, and a decennial, or still more seldom, clearing of the nuth grass by means of the large plough. It is irrigated solely by the dews and rains of heaven.

The chemical composition of the cotton plant it produces, somewhat assimilates in its ingredients that of the soil, as Dr. Macleod's analysis, subjoined, shows. In addition will be found the alkali of the vegetable, and the muriate of soda, which, as well as the carbonate, are frequent accidental ingredients in the composition of the regur. They sterilize it when present in large quantities. The proportion of silex in the cotton plant, as might naturally be expected, is much less, and the alumina is altogether wanting.

Silex	7	0
Alumina	0	0
Carbonate of lime	45	6
Carbonate of magnesia	25	0
Charcoal, oxide of iron, and loss	5	2
Carbonate of potass	10	6
Muriate of potass and soda	6	6
	100	0

The regur is remarkably retentive of moisture; a property to which is ascribable much of its fertility, since it has been ascertained by the experiments of Sir Humphry Davy that the absorbent power of many soils with respect to atmospheric moisture are greatest in the most fertile soils. He dried[1] 1000 parts of a celebrated soil from Ormiston in East Lothian, by a heat amounting to 212° Fahrenheit, and found that by one hour's exposure to air saturated with moisture at a temperature of 62° it gained 18 grains. Dr. Christie thoroughly dried a portion of régur by a heat nearly sufficient to char paper. He then exposed to the atmosphere of a moderately damp apartment 2615·6 grains of it, and found after a few days it had gained 147·1 grains. He now exposed it to an atmosphere saturated with moisture, and found that the weight increased daily till the end of a few weeks, when it was found to be 2828·4 grains. The soil had therefore gained 212·8 grains, or about 8 per cent.

During the dry season, when the crops are off the ground, the surface of regur, instead of presenting a sea of waving verdure, exhibits the black drear aspect that the valley of the Nile puts on under similar circumstances, and which powerfully reminded me of the régur tracts of India. Contracting by the powerful heat of the sun, it is divided, like the surface of dried starch, by countless and deep fissures, into figures usually affecting the pentagon, hexagon, and rhomboid. While the surface for a few inches in depth is dried to an impalpable powder raised in clouds by the wind, and darkening the air, the lower portions of the deposit, at the depth of eight or ten feet, still retain their character of a hard black clay, approaching a rock, usually moist and cold; when the surface dust, as I have proved, has a temperature of 130°. In wet weather the surface is converted into a deep tenacious mud.

Over the vast and fertile table lands where this soil prevails, rice, the staple article of food on the maritime and low tracts, is no longer, or but seldom, used by the lower classes, and cakes of wheaten flour, or of that of the juari and bajri are substituted.

The purest beds of regur contain few rolled pebbles of any kind; the nodules of kunker we see imbedded have probably been formed by concretion from the infiltration of water charged with lime; and it is only near the surface that the regur becomes intermingled with the recent alluvium of the surrounding country, or in its lower portions where it becomes intermingled with the debris of whatever rock it happens to rest on,—trap and calcedonies in trappean districts; granite,

[1] Madras Journal of Literature and Science, for October, 1836, p. 472.

sandstone, pisiform iron ore, and limestone, in the plutonic and diamond sandstone areas. It sometimes exhibits marks of stratification: in Gujarat, Professor Orlebar informs me, the regur is distinctly stratified; and a writer on the Geology of the Hydrabad country, in the Madras Literary Transactions, (Part I, p. 82) observes, that the cotton soil there varies in depth from a few feet to many fathoms; and that it is generally found distinctly arranged in strata, which are sometimes separated by thin layers of sand or gravel. These strata, he observes, vary in thickness; they are sometimes horizontal; in other instances waved, or more or less inclined to the horizon.

Organic Remains.—No organic remains have hitherto been discovered in the regur, except a few fluviatile exuviæ on the banks of rivers, and land shells, all of existing species.

Origin.—Drs. Voysey and Christie, chiefly from the circumstance of the regur fusing into a dark glass and slag resembling the trap, and its dark colour, and its embedding minerals from the trap formation, are of opinion that it arose from the weathering of trap rocks.

In a paper read before the Bengal Society, in March, 1838, I stated my reasons for venturing to question the accuracy of this theory. They are briefly these,—that the trap rocks of India never weather into a black soil, but are seen every where to disintegrate into a red, brown, light or rust-coloured earth and detritus, as the protoxide of iron they contain, by exposure to the air, becomes converted into the peroxide, like a piece of iron which first blackens, and then rusts, on exposure.

The depth, extent, and situation of the sheets of regur, often far above the beds of existing rivers, and out of the reach of their greatest inundations capping both the tabular summits of hills, and the plains at their base, preclude the supposition of its being a fluviatile deposit as thought by Voysey. Besides, I found that the deposit of the large rivers running through the great regur tracts of the Deccan, viz., those of the Bima, the Kistna, and the Tumbuddra, differed widely from the regur, consisting principally of a reddish-brown silt, mud and sand, containing calcareous matter, partly deposited in it by calcareous springs, and partly the detritus of the beds of limestone and kunker, over which the course of the river occasionally passes. This silt and sand deposit sometimes acquires a dark hue from the admixture of the regur itself, which often forms the banks of these rivers, and which during the freshes are frequently undermined, and washed into the stream.

It is evident from the regur's resting indiscriminately on plutonic, hypogene, trappean, and aqueous rocks of widely dissimilar chemical

composition, with some of which it exactly agrees, that it cannot be the result of the weathering of these different rocks, *in situ*, nor can its present elevated situation on these rocks be accounted for by fluviatile, or other transporting powers now in action. Its lying under all present alluvia is indicative of its greater relative age.

Its mineral composition, colour, the horizontality of its surface, cracked by countless fissures, assimilates more the black vegetable deposit we often see in the tanks of India, or the dark flat mud deposits of the Nile, which, like the cotton soil, I found to melt before the blowpipe into a greenish glass or enamel, to fall to pieces in water with emission of air bubbles, forming a tenacious clay, and to contain a considerable quantity of calcareous matter.

The components of the Nile deposit are the same precisely as those of the regur, as will be seen by the subjoined analysis by Regnault, but the proportions are different. That of the lime is nearly the same same in both. The mud of the Nile would appear to contain much more aluminous and less siliceous matter than the regur, but the proportions I found in both deposits to differ in different localities.

Mud of the Nile.

Silex	4 0
Alumina	48 0
Carbonate of Lime	18 0
Carbonate of Magnesia	4 0
Oxide of Iron	6 0
Water	11 0
Carbon (or extractive)	9 0
	100 0

The mud of the Nile is supposed to obtain most of its vegetable or carbonaceous matter from the overflowing of the great marshy lakes that lie stagnant on the table lands of Abyssinia during great part of the year. I have never been able to discover organic remains in it, nor have I heard of such being found, save pebbles from the subjacent shell limestone, and a few existing fluviatile and terrestrial exuviæ.

That the regur of India is an aqueous deposit from waters that covered its surface to a vast extent, I have little doubt: but it would be as difficult to point out at the present day the sources whence it derived the vegetable matter, to which in great measure it owes its carbonaceous colour, and the rocks, from the ruins of which its remaining components were washed, as to indicate the locality of the continent from the vast debris of which the Wealden beds were formed, and by the drainage of which a great river was supplied.

Shortly previous to my leaving England in 1842, I was present at

a Meeting of the Geological Society, at which a specimen of the black soil, the *Chernoi zem*, that covers many of the steppes of Russia, and brought thence by Mr. Murchison, was exhibited, when both Mr. Lonsdale and myself were struck with the external resemblance this deposit bears to the regur. Its geological position and distribution also appear to be similar.

Kunker Formation.

It is probable that the calcareous deposit termed *Kunker*, a Hindustani word (کنکر), but of Sanskrit extraction, signifying a nodule of limestone, or a pebble of any other rock, had an earlier origin than the laterite and some of the marine alluvial beds just described: but since it has not, as yet, been found underlying them as a separate and distinct bed, without penetrating into their substance, it will be best for the present to assign it a place between them and the regur—that is, its earliest deposits; since the process by which it was originally formed, although now less active, perhaps, than in former epochs, has not altogether ceased. There will be always some difficulty in distinguishing between the kunkers of different eras, the recent deposit differing little from the ancient in chemical composition, but being generally of a whiter colour, softer, and of a more cancellar structure.

Geographical Position and Extent.—The kunker formation is irregularly distributed in overlying patches over perhaps one-eighth of our area. I know of no tract entirely free from it, with the exception, it is said, of the summits of the Nilgherries. I have seen it, however, at the height of 4000 feet above the sea among the ranges on the elevated table lands. It is most abundant in districts penetrated and shattered by basaltic dykes, and where metallic development is greatest: for instance, in the copper district of Nellore, and the chrome and iron tracts of Salem. It is, perhaps, least seen in localities where laterite caps hypogene or plutonic rocks.

Geognostic Position.—It occurs filling, or partially filling, fissures and chinks in the subjacent rocks, in nodular masses and friable concretions in the clays and gravels above the rocks, and in irregular overlying beds, varying from a few inches to forty feet in thickness. It has been found at the depth of 102 feet below the surface of the surrounding country, prevails alike in granite, the hypogene schists, the diamond sandstone and limestone, and in the laterite: hence, the springs which deposit it must bring up their supply of calcareous

matter from sources deeper beneath the earth's crust than the diamond limestone.

Lithologic Character and Imbedded Organic Remains.—The older kunker is usually of a light brownish, dirty cream, reddish, or cineritious grey tint; sometimes compact and massive in structure, but more usually either of a nodular, tufaceous, pisiform, botryoidal, or cauliflower-like form. Its interior is sometimes cancellar, or slightly vesicular; but compact or concentric in the pisiform and nodular varieties. Its interior structure is rarely radiated. When compact it resembles the older travertines of Rome and Auvergne. It aggregates in horizontal overlying masses, usually intermingled with the soil without much appearance of stratification. It is broken up, and used as a rough building stone in the bunds of tanks, walls of inclosures, &c., by the natives, and is universally employed to burn into lime.

A specimen of kunker, analysed by the late Mr. J. Prinsep, yielded,

Water of absorption . . .	1 4
Carbonate of lime . . .	72 0
Carbonate of magnesia . . .	0 4
Silex	15 2
Alumina and oxide of iron . .	11 0
	100 0

Some varieties contain so much silex as to give fire with steel: others are almost entirely composed of earthy white carbonate of lime, and crumble between the fingers.

Organic Remains.—No organic remains have hitherto been discovered in the ancient kunker of Southern India; but in the modern kunker I have seen pottery, bones of recent mammalia, fragments of wood, existing land and freshwater shells, Paludinæ, Helix, Planorbis, and Ampullaria, imbedded.

In the banks of rivers, it is often seen concreting in stalactiform masses round the stems and roots of grasses, which, decaying, leave casts of carbonate of lime. This lime held in solution and suspension by existing streams, mingling with the fine particles of sand and ferruginous matter in suspension, sets under water like pozzolana; and, uniting the shells, gravel, sand, and pebbles in the bed, and on the banks, forms a hard and compact conglomerate.

Origin.—The kunker, as may have been collected from what has been just stated, is not of zoophytic origin like coral reefs; nor does it appear to have been generally deposited, or chemically precipitated, from the waters of an ocean or inland lake: but, like the travertines of

Italy, it may be referred to the action of springs, often thermal, charged with carbonic acid, bringing up lime in solution, and depositing it as the temperature of the water gradually lowered in rising up to the earth's surface, or in parting with their carbonic acid.

After depositing a portion of calcareous matter in the fissures of the rocks by which it found a vent, the calcareous water appears to have diffused itself in the loose debris, regur, gravels, and clays usually covering the rocks; and, by force of chemical affinity, the disseminated particles of lime gradually congregated into the nodular, and other forms we see them assume. These nodules are sometimes arranged in rows like the flints in chalk; and from some of them project delicate spiculæ of carbonate of lime, which would have been broken off had they been drift pebbles, as supposed by some.

If we compare the calcareous matter found in the fissures of the rock with that of the nodules above deposited by the same spring, we generally find the former in a much purer state, and more friable than the latter, which, by being disseminated among the detritus above has, as previously remarked, become mingled with such proportions of siliceous and ferruginous matter as to assimilate in composition some of our hydraulic cements: hence its disposition to consolidate and harden in moist clays, sands, and detritus. The dissemination of the calcareous particles among heterogeneous earthy matter would appear favourable to their aggregation by mutual attraction, in a nodular or concentric form, round the nucleus of a grain of sand, or blade of grass. Some of these nodules and spheroids may be regarded, perhaps, as exhibiting approaches to crystallization,—in fact, crystalloids: the interior structure, particularly of the pisiform variety, is frequently crystalline, and exhibiting no traces of mechanical concentric accumulation round a nucleus.

The structure of the kunker formation may be generally termed, therefore, concretionary, like that of some varieties of magnesian limestone. But there is this striking distinction in the kunker, viz., the absence of the laminæ and lines of original deposition that pass uninterruptedly through those of concretions in the magnesian limestone: hence the inference that the concretionary structure in the latter took place subsequent to deposition; and in the kunker that the deposition of the lime must have taken place under different circumstances, and that the aggregation of its molecules was almost contemporaneous with the exercise of the force which drew them into a concretionary structure. It is evident that both mechanical laws and those of crystallization have influenced the various aspects under which we see this singular rock.

Dr. Christie[1], who was of opinion that the regur was the result of the decomposition of the trap rocks, as already alluded to, thought that the kunker, from its being often associated with it, owed its origin to the calcareous spar of the trap rocks. The kunker, however, as we have seen, may be observed in the process of being deposited by springs rising through granite, gneiss, hornblende, limestone, and sandstone rocks, in areas where not a trace of the newest trap, or even of the older trap, which rarely contains calc spar, is to be seen. The small quantity of lime that enters into the composition of hornblende and augitic rocks is infinitely too minute to account for the prodigious development of this concretionary limestone seen all over India.

Age.—I have already alluded to the difficulty of fixing the period at which kunker was first deposited; and the formation is still going on, imbedding fragments of the oldest rocks with those of the most recent, and daily adding to the deposit both on the land and in the bed of the ocean, into which large quantities of calcareous matters are poured by the springs which empty themselves into the great lines of drainage.

The facts of the kunker never having been observed to form a regular bed on which another deposition has taken place lower than the regur, its never being divided by any of the veins or dykes in any of the rocks described, and being undisturbed and unaltered by the overlying trap, which we have seen breaking up and converting into chert the freshwater limestones of Nirmul, and the few shells it imbeds being all of existing species, induce me to place it in the new or pliocene epoch, which includes those of the recent, or human period. It is probable that its earliest appearance took place at an era anterior to this, but there is no decisive evidence of its being older than the newer pliocene travertins of Rome, which imbed the existing land and freshwater shells of the surrounding country and the remains of the mammoth.

Rock Basins, &c.—In a Paper read before the Geological Society, in 1841-1842, I communicated some observations on the occurrence of Rock Basins, the Giants' Cauldrons of the Scandinavian Mountains, in the rocks of Southern India, at elevations beyond the reach of present floods; and others in the rocky beds of rivers evidently eroded by the action of present streams, which closely resemble those described by M. Agassiz, on the sides of the valleys of the Alps, and like them pass into spoon-shaped excavations, and into successions of

[1] Madras Journal of Literature and Science, for October, 1836, p. 470.

cavities connected by narrow channels in the rock. M. Agassiz, from the circumstance of many of the cavities occurring in rocks remote from the influence of modern running waters, and observing that similar cavities and channels are now in process of excavation by the streams of water which flow along the surfaces of glaciers, and then fall into fissures which are open to the bottom, conceived them to be evidences in favour of his glacier theory, as confined to these icy tracts: but in the paper above alluded to, I think I have satisfactorily proved the fact of their being caused in the rocks of the Tumbuddra and other streams of Southern India, where ice is unknown, by the waters that now roll over them; and consequently, that a glacier is not an indispensable condition to the production of these singular cavities, which I have also observed in the granite rocks in the heart of the desert of Mount Sinai, and in the limestones of Egypt, Sicily, and Malta, easily distinguished by their regular form and contour from the perforations of lithodomi.

The parallel striæ and scorings (*diluvial schrammen*) so remarkable on the mountains of Northern Europe, adduced by Sefström as evidences of a vast ancient flood, caused by the abrasion of pebbles swept over the surface by aqueous currents, the polished surfaces and grooves so generally received in Europe, on the authority of Agassiz, Charpentier, and others, as unquestionable evidence of the overland march of glaciers, carrying with them boulders, gravel, and sand, which are often impacted in the ice, like particles of sand in sand-paper, and scratch or polish the subjacent rocks, have escaped the notice of Indian geologists. A few grooves occur on the surface of the granitic bosses that rise from the surface of the sandy waste that marks the confluence of the Hogri with the Tumbuddra; but these have the appearance of having been worn by the action of the present floods; they are chiefly from one to two inches in breadth, coinciding with the diameter of the generality of the pebbles found in the river bed, and their direction runs parallel with that of the stream by which they are covered during the monsoon. The depth of the furrows varies, and in some places has been influenced by the hardness or softness of the parts of the rock. A few tough quartz veins have been much less worn than the imbedding rock, and are seen standing out, in high relief, from its surface: some, indeed, have even formed barriers, but slightly worn, across the furrows.

Some grooves occur on the surface of the limestones of Cuddapah, Kurnool, &c., but they appear to me to have been caused by the unequal decay or weathering of the rock.

PART VIII.

Modern Alluvia and Sand Dunes.

Where regur does not prevail, the ordinary soils of Southern India are distinguished by a reddish tinge, owing to the great prevalence of oxide of iron in the rocks of which they are, in great measure, the detritus. Patches of white soil occur, and are usually the consequence of the weathering of beds of quartz, or composed of kunker, which abounds so generally, and enters into the composition of almost every variety of soil. These white soils, it is almost unnecessary to remark, are characterized by sterility.

In tracts of country shaded by eternal forests, for instance the Ghauts, and sub-Ghaut belts, a dark vegetable mould prevails,—the result of the successive decay and reproduction of vegetation for a series of ages, under the stimulating alternations of excessive heat and moisture; in such regions, where unsheltered by forest, and in exposed situations, the soil is either lateritic or stony according to the nature of the subjacent rock.

The substratum of the modern soils of Southern India is usually either a bed of kunker, or the parent rock, with an intervening layer of rubble, composed of its own broken up, and angular fragments of the subjacent rock, often called *Mhurrum* by the natives.

At the bases of mountain ridges we usually find an accumulation of large angular blocks composed of the same rocks as the hills down whose declivities they have rolled in weathering; at a greater distance from the base in the plain these are succeeded by pebbles, whose reduced size, mineral composition, and worn angles proclaim them to have travelled from the same source, diminishing in bulk the farther we recede from the mountains, until they pass, by the gradations of grit and sand, into deposits of a rich clay or loam. Such are the gradations generally to be traced in the modern rock alluvia, and which strikingly distinguish them from the vegetable soil of the forest tracts and the regur, which are often seen in the state of the greatest richness and fineness of composition at the very bases of the hills, and resting immediately on the solid rock.

The alluvia brought down by the streams from the Western Ghauts, flowing easterly to the Bay of Bengal, are usually composed of silt, sand, and gravel—detritus of the rocks over which they have passed: they almost always contain a considerable portion of lime derived from the springs which supply them, and from the limestone

and kunker beds over which most of them flow. The alluvia of the rivers of the western coast are of a more carbonaceous, and less calcareous character, owing to the greater absence of lime in the formation, and the dense forests and luxuriant vegetation which almost choke their passage.

During the hot season, when the surface of the alluvial sand in the beds of the rivers and rivulets is perfectly dry, a stream of clear water is frequently found at various depths below them, stealing along or lodging in the depressions of some impervious layer of clay or rock, to which it has sunk through the superincumbent sand. So well is this fact understood by natives, that in arid, sandy tracts, where not a drop of water is to be seen, they will often be enabled to water whole troops of horse and cattle by sinking wells a few feet deep, through the sands of apparently dried-up rivulets. I have observed similar accumulations of water at inconsiderable depths below the surface of the sands of the Egyptian deserts, which the wandering Bedouin is as keen to take advantage of as the vagrant Brinjari of India.

The benefit resulting from the admixture of lime into soils consisting almost solely of vegetable, siliceous, or argillaceous matter, is too well known to be dwelt on here; and it is a remarkable and bountiful provision of nature in a country like Southern India, where limestone is so rarely seen in the rocks from which a great part of its soil is derived, that innumerable calcareous springs should be constantly rising through the bowels of the earth to impregnate its surface with this fertilising ingredient.

In many parts of the Ceded Districts, where the surface soil has been of a gravelly sterile nature, I have seen it covered with little conical heaps of the subjacent rich black regur, thrown up there by the subterraneous workings of a small insect of the ant species.

The alluvia of Southern India are remarkable for their saline nature. The salts by which they are impregnated are chiefly the carbonate and muriate of soda, which prevail so much, (particularly in mining districts,) as to cause almost perfect sterility. The carbonate appears on the surface covering extensive patches, in frost-like efflorescences, or in moist dark-coloured stains, arising from its deliquescence in damp weather, or by the morning dews.

Where such saline soils are most prevalent there will be usually a substratum of kunker, or nodules of this substance, mixed with the soil: and there can be little doubt, I think, that their origin may be referred to the numerous springs rising through the fissures or

laminæ of the subjacent rocks, some charged, as already noticed, with carbonate of lime, and others with muriate of soda and sulphate of lime. The carbonate of soda, like the natron of Egypt, is the result of a mutual decomposition of the muriate of soda and carbonate of lime, by a natural chemical process so satisfactorily explained by Berthollet. It may be as well to remark that muriate of lime is invariably found in the saline soils of India, and which are known to the natives by the terms of "soud" and "jairi." The soda soil is used by the *dhobis*, or washermen, to wash clothes with, and hence called in Hindustani, *dhobi ki matti*, washerman's earth: it is also employed by the natives in the manufacture of glass.

Both the carbonate and muriate of soda are found mingled in varying proportions, in white efflorescences, in the beds and on the banks of springs and rivulets.

Nitrous Soils.—Soils impregnated with nitre I have seen only on and around the sites of old towns, villages, &c., and other localities occupied by man or beast, though they are said to occur in the deserts of Ajmere, and other localities remote from the impregnation of animal matter. In Egypt I observed that the richest nitre soils were invariably procured from the sites of old cities, Luxor, Carnac, Dendera, Sakára, Memphis, Ghizeh, Old Cairo, &c., and it appears to me that the abundance of nitre for which the soil of Egypt has so long been famous, is, in great measure, owing to so enormously dense a population being confined to the narrow belt of cultivable soil deposited by the Nile.

Here a vast quantity of animal matter must gradually have been blended with the calcareous and vegetable soil: from their decomposition the elements of new combinations, by the agency of new affinities, are generated;—nitrogen from the animal, and oxygen, &c. from the vegetable matter. The nitric acid thus produced combines with the vegetable alkali, forming the nitrate of potass, while its excess, if any, combines with the lime, forming a deliquescent salt,—the nitrate of lime. The affinity lime has to nitrogen and oxygen materially assists the formation of the acid by their combination.

The natives of India, in their rude manufactories of saltpetre, act upon these principles without being aware of their rationale. Having collected the earth from old ruins, or from places where animals have been long in the habit of standing, they throw it into a heap mingled with wood ashes, old mortar, chunam, and other village refuse; and allow it to remain exposed to the sun's rays and to the night dews for one or two years, when it is lixiviated. The salt obtained is not very

pure, containing either the muriate and sulphate of soda or potash, or nitrate and muriate of lime.

Moisture and a certain degree of heat appear to be necessary conditions to the production of nitre in soils; hence its comparative rarity, in the natural state, in the soils of countries remote from the heavy dews and heats of the tropics; South America, Africa, Persia, and India, are the countries where it most abounds. It has, however, been found so far north as Hungary and Spain. Even in the artificial nitre beds of Europe much heat is evolved in the fermentation of the decomposing animal and vegetable matter of which these composts are formed.

The presence of animal matter is thought by some not essential to the formation of nitre, since it has been found encrusting the interior of caverns where no trace of the former has been found. The Pulo of Molfetta, in the Neapolitan dominions, is a deep cavity formed by the falling in of several caverns; and, when the Abbé Fortis first drew public attention to it, it was lined with a crust of nitre an inch thick; which, on being scraped off, was successively renewed in a few days. In Ceylon[1], a cavern near Mensoora, in the district of Doombora, in a decomposing rock consisting of calcspar, felspar, quartz, mica, and talc, in a humid state, exposed to the air, and perfectly free from any animal matter, contains a rich impregnation of nitre. It also occurs in the limestone caverns of Kentucky in North America. It would appear in these cases to be deposited like stalagmitic encrustations of lime by water percolating through fissures in the rocks forming the sides and roofs of the cave, and these waters have not hitherto been traced to the source; and it is very probable they may have arrived at these nitrous caves impregnated with saline matter derived from beds of animal remains in other caves occupying a higher level. Another source of potass, where such depositions occur in felspar rocks, as in Ceylon, may be traced to the decomposing felspar itself, which contains from twelve to fourteen per cent of potass.

Nitrous soils are easily recognised both in Egypt and India by the dark moist-looking patches which spread themselves irregularly on the surface of the ground, and, by capillary attraction ascend walls of considerable height. They are more observable in the morning before the sun has had power to dissipate the dews.

Sulphuriferous Alluvia.—Soil impregnated with sulphur occurs in a low situation in the Wodiapollum jungle, south of Wolandurpett,

[1] Davy's Account of the Interior of Ceylon, 4to., p. 32.

South Arcot. The specimens I have seen of this soil were of a dark greyish colour, consisting of a number of fine particles of earth, like those of a sediment from water, agglutinated in small friable lumps, which, on being broken, exhibited minute yellow spiculæ and crystals of sulphur. The natives inform me that after a fall of rain the sulphur is apparent on the surface of this deposit.

Another deposit, according to Heyne, occurs in the Northern Circars, not far from Madapollam, in the bed of a shallow marine lagoon connected with the Godavery, at a place called Saura sanyá-veram, about twelve miles east from Ammalapoor. This lake has a most disagreeable smell: the sulphur is found in its deposit at a depth never greater than a foot below the surface of the mud, in semi-indurated nodules of a greyish yellow colour, which exist in considerable abundance. This saline sulphureous lake is of recent origin: fifty years ago it was a cultivated field. The soil is the black cotton regur mixed with decayed vegetable matter, and the water covering it is impregnated with the usual salts of sea-water.

Dr. Malcolmson has the merit, I believe, of having first suggested the hypothesis of the sulphuretted hydrogen in the saline lakes being originated by the decomposition of the sulphates in the water by the carbonaceous matter of vegetables, a theory the truth of which has been tested and found correct by Professor Daniell, in his investigation as to the causes of the rapid decay of the copper sheathing of ships employed on the Western Coast of Africa, which was so remarkable as to attract the notice of the Lords of the Admiralty; and which he has satisfactorily shown to be ascribable to the sulphuretted hydrogen which is spontaneously evolved in large quantities from the waters of the rivers on the coast; and to which the deadliness of these tracts may be, in great measure, attributed.

There can be no doubt that sulphuretted hydrogen has been similarly generated in the lagoon in the Northern Circars, viz., by the decomposition of the sulphates of the sea-water by the vegetable matter of its bed, and that the sulphur, of which sulphuretted hydrogen contains more than ninety-four per cent., has been deposited either by atmospheric exposure on the drying up of the water in the hot season, or by the hydrogen being set free by a new force of chemical affinity. It is a well known fact that water impregnated with sulphuretted hydrogen deposits its sulphur on exposure to the air. In the decomposition of a gas, or miasma, so deleterious to life, by contact with the air we breathe, we may behold the benevolent finger of Providence; still, in some cases, as on the baneful Western Coast of

Africa, the generation of the gas goes on in a disproportionate ratio to its decomposition.

Many of the salt and fresh-water lakes and marshes on the coasts of Southern India emit fetid odours of sulphuretted hydrogen during the hot weather, and it is probable that sulphur will be found deposited in their muddy bottoms.

I have seen sulphur encrusting crevices in the lava walls of the craters of Etna and Vesuvius, dug out in large crystals from the Solfatara near Naples, and in detached nests in the limestones of Egypt and Sicily, and the gypseous rocks of Conil, near Cadiz. It also occurs in the hot volcanic springs of Iceland, and has been found in detached masses in cavities in quartz veins in the mica slate, composing the Ticsan mountains in South America. In all these cases it appears to have originated by sublimation by active or extinct volcanic or thermal heat from below. Its occurrence, as a deposit, originating in the decomposition of salts held in aqueous solution by carbonaceous matter, is interesting and instructive.

Auriferous Alluvia of Rivers.—The alluvium brought down by the rivers flowing easterly towards the Bay of Bengal is usually silt, sand, or calcareous matter, detritus, as before observed, of the rocks over which they pass; while that of the rivers flowing westerly is of a more carbonaceous character. Most of these alluvia are auriferous, particularly those of the Malabar and Canara coasts. Grains of gold are found in considerable abundance in the alluvial soils of Mysore, Malabar, &c., and in those of the Kupputgode range in the Southern Mahratta country.

Dunes.—Dunes, or hills of moving sand, are frequent along the Malabar coast, contributing greatly to the formation of those singular lagoons termed backwaters, by obstructing the mouths of rivers, and preventing the free drainage of the country. The water brought down by the stream from the Ghauts accumulates in a series of lagoons and marshes, extending along the coast in a line nearly parallel with it. The sea occasionally communicates with the fresh-water by breaking over the narrow belts of sand that usually separate them from the ocean, or by bursting through the openings frequently made by the force of the freshes during the monsoon. Hence we find in their beds the shells of the sea mingled and sometimes alternating with the Planorbes, Helices, Ampullaria and Pupas of the land and fresh water.

Similar dunes occur on the eastern coast, particularly near the embouchures of the larger rivers,—such as the Godavery and the Kistna. These banks of sand, by their constant shifting, frequently

assist the singular changes in the mouths of the rivers effected by the more powerful and direct influence of the sand bars thrown up in the conflict between the river freshes and the tidal wave during the fury of the monsoon.

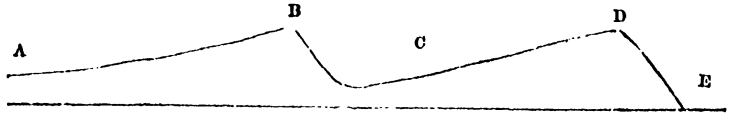
Sand dunes are not confined to the coasts, but are seen on the banks of the larger rivers in the interior of the peninsula, and on the table lands. During the dry season, the beds of these rivers, deriving but a scanty supply of water from perennial springs, usually present large arid wastes of sand. These are acted upon by the prevailing westerly winds, which blow strongest during the months of June, July, and August, and raise the sand into drifts, which usually advance upon the cultivation in an easterly direction.

At Honoor, in the Ceded Districts, on the banks of the Hogri, about twelve years ago, at a season when the westerly winds were unusually strong, and but little rain had fallen, the dunes invaded and buried land under cultivation, in one year alone, to the extent of more than eight chains, not since reclaimed. The next year they threatened the village itself, and the sand rose in its streets to the height of five feet. The village of Bodúrti, about eight miles distant, was totally buried about thirteen or fourteen years ago. At the time of my visit, in 1839, it was completely covered by the sand drift, with the exception of the tops of the walls. On the banks of the Pennaur, in the Cuddapah district, I have ridden over a whole village overwhelmed by a sand dune: the only indication of its site was the top of an old pagoda projecting from the sand.

The advance of these moving hills is usually very regular where no obstruction presents itself, such as high bushes, trees, hedges, &c., which are often planted by the natives purposely to arrest the progress of these invaders on their cultivated lands. The sand is often held together and retarded by the embraces of the long fibrous plants that grow up and are interwoven with its layers: the *Kakivéru*, *Jihar chettu*, and the Ag bush (*Asclepias gigantea*), are those that most frequently occur. The hills of blown sand near Honoor present a gentle slope to windward, up which the particles of the sand are moved by the wind, and fall over on the leeward side at an angle of about 45°.

A precisely similar contour assumed by heaps of particles of sand acted upon by currents of air, on the small scale, has been noticed by Mr. Lyell, in describing the production of the ripple mark on the sands of Calais; and his explanation of the process by which these hills in miniature are obliterated, reproduced, and advance over the graves of their predecessors, will equally apply to the formation and advance of the sand hills of Honoor. "The mode of the advance,"

says he[1], "was by continual drifting of grains of sand up the slopes A B and C D, many of which grains, when they arrived at B D, fell over



the scarps B C and D E, and were under shelter from the wind, so that they remained stationary, resting, according to their momentum, on different parts of the descent, and a few only rolling to the bottom. In this manner each ridge was distinctly seen to move slowly on as often as the force of the wind augmented. Occasionally part of a ridge, advancing more rapidly than the rest, overtook the ridge immediately before it and became confounded with it, thus causing those bifurcations and branches which are so common." In some cases fluviatile shells have been blown up and imbedded in the sand; ripple marks left by the wind on their surfaces, and the process of consolidation, is alone wanting to transform the sand of yesterday's accumulation into a fossiliferous ridge.

I have observed similar sand drifts to be frequent in the Libyan desert, whence impelled by the westerly winds, they are sure to advance on and threaten the fertile valley of the Nile; and where, as in India, they have overwhelmed many of the ruins of ancient Egypt. The phenomenon of *Jebel Nakús*, (described in a previous paper,) in the wilderness of Sinai, I found to proceed from a heap of fine sand drifted on the steep side of a ridge of sandstone hills, and covering it from base to summit.

Those singular local whirlwinds, called *pisáchas*, or Devils, by the natives, whirl up sand in their eddies to an enormous height, and transport it across hills, rivers, and sheets of water of considerable magnitude. They are often strong enough to carry up pebbles, and land, marine, and freshwater shells, which are thus occasionally deposited in situations above the drainage level of the country, at a distance from their native beds, and in situations where it would be otherwise difficult to account for their presence, except by the agency of the aquatic and other birds that prey on the tenants of shells.

[1] Lyell's Elements, Vol. I., p. 43.

[To be continued].